TRANSPORTATION INFRASTRUCTURE RESEARCH AND TECHNOLOGY

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
INVESTIGATIONS AND OVERSIGHT

AND THE

SUBCOMMITTEE ON TRANSPORTATION,
AVIATION AND MATERIALS

OF THE

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TRANSPORTATION INFRASTRUCTURE RESEARCH AND TECHNOLOGY

THURSDAY, JUNE 9, 1983

HOUSE OF REPRESENTATIVES, COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON INVESTIGATION AND OVERSIGHT AND SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS,

Washington, D.C.

The joint subcommittees met, pursuant to call, at 9:35 a.m. in room 2325, Rayburn House Office Building, Hon. Dan R. Glickman (chairman of the Subcommittee on Transportation, Aviation and Materials) presiding.

Mr. GLICKMAN. Good morning.

Today the Subcommittees on Transportation, Aviation and Materials, and on Investigations and Oversight of the Science and Technology Committee are pleased to begin a series of hearings on transportation infrastructure research and technology.

The highways and bridges of the United States, essential components of our Nation's infrastructure and economic well-being are rapidly deteriorating. The typical interstate highway is designed to last 20 years before it requires major rehabilitation, and 41 percent of the Interstate Highway System has already reached this milestone.

Forecasts indicate that by the year 1990, 75 percent of the Interstate Highway System will have reached the 20-year milestone, while also being subjected to traffic at a level of 150 percent of the capacity these highways were designed to handle. Perhaps the most alarming example of the condition of our highway infrastructure is the fact that 23 percent of the Nation's bridges have been identified as structurally deficient.

Although the recently enacted Surface Transportation Act will provide increased funding for highway and bridge rehabilitation, we must also renew our commitment to the research that supports that effort. This committee is particularly interested in assuring the use of improved technologies, materials, and construction methods to insure that Federal highway funds are used in the most cost-effective manner possible. We hope to contribute to this effort today.

I welcome the expert witnesses that have agreed to appear before us today and look forward to some very productive hearings.

I would like to call on my co-chair in this effort, my colleague from Tennessee, Congressman Gore, chairman of the Investigations and Oversight Subcommittee.

Mr. GORE. Thank you very much.

I am pleased that our two subcommittees can conduct this rather extensive inquiry into transportation infrastructure research and technology. This series of hearings, as will become apparent during their course, is a nuts-and-bolts inquiry. It is difficult, it is going to take some time but we are convinced that it will have a payoff.

Our Nation is about to undertake a major new investment in infrastructure and it only makes sense to look carefully at the research needs that should accompany that effort.

Principally we will focus on the research needs and efforts to be directed at highway and bridge repair and maintenance. The Department of Transportation has estimated that nearly 10 percent of the approximately 41,000 miles of the Interstate Highway System are in need of immediate or near-term resurfacing or replacement.

By 1995 that figure is expected to jump to 65 percent if trends are not changed. Fully 50 percent of the entire Federal-aid primary highway system will reach the end of its original design life before 1990. Notwithstanding the health of the Brooklyn Bridge, which last month celebrated its 100th birthday, the state of the Nation's bridges is equally troubling. Of the 557,616 bridges in the United States, the Federal Highway Administration—FHWA—lists 126,655 as structurally deficient and another 121,702 as functionally obsolete.

Considering both the importance of our Nation's highways to commerce, industry, and recreational activities and the staggering estimates of repair and replacement cost—placed by some at a major part of the total cost of trillions of dollars—the need for and importance of a well-directed and targeted research effort becomes clear.

During our hearings, we will hear from academic, research directors, business executives and from State and local officials and from the Federal Department of Transportation.

As we listen to these witnesses, we will seek to assess whether the scope, organization, direction, effectiveness and funding level of the current research effort is adequate to meet the challenge. We will be looking for suggestions to improve our current efforts so that we can more economically and effectively rebuild the Nation's highway transportation infrastructure.

We begin today with an excellent set of witnesses.

Mr. GLICKMAN. Thank you, Al.

I would next call upon Bill Carney of New York, who is ranking minority member of the Transportation, Aviation and Materials Subcommittee.

Mr. CARNEY. Thank you, Mr. Chairman.

The questions we will attempt to answer in these 3 days of hearings should be of interest to all of us. How can we continue to provide highways necessary for a growing and increasingly mobile population? Last year passenger cars alone accounted for over 1 trillion miles and they are responsible for only a small fraction of the wear and tear on our Nation's highways.

It has been estimated that one five-axle truck weighing 80,000 pounds does as much damage to a highway as 9,600 cars and there will be over 50 billion miles driven by heavy truck-trailer combinations next year.

It is clear that we have a difficult task ahead of us. How can we maintain the 3.9 million miles of streets and highways that we now have and continue to build more with the limited resources available. This is the challenge that we face.

The Surface Transportation Assistant Act of 1982 provides significant increases in funding for the transportation infrastructure. Over $55 billion in new money will be provided for the repair and improvement of our Nation's highways and bridges and also for the capital investment in new ones. Fuel taxes will more than double to pay for this. We want to be sure that these dollars are spent effectively.

It is always difficult to spend money on research when there is a pressing problem that needs immediate attention and certainly that is the problem that we face with much of our highway infrastructure today. However, it should be clear that if we don't want another tax increase in the near future, we will have to find a better way to manage our transportation needs. We need to develop new technologies, new materials, and new methods of construction to build the highways and bridges of the future.

We need to find less destructive ways to remove ice and snow from the highways and we need to develop more cost-effective means of repairing the existing roadways. These are just some of the many problems facing us with our transportation infrastructure. I welcome our distinguished witnesses here today and look forward to hearing their views.

Thank you very much.

Mr. GLICKMAN. Thank you, Mr. Carney.

Mr. Joe Skeen, ranking member of the I&O Subcommittee.

Mr. SKEEN. Thank you, Mr. Chairman.

I have a statement that I would ask unanimous consent that it be entered in the record. I think that this Congress has evidenced a great concern on this particular issue and I am looking forward to the testimony and to save time, Mr. Chairman, I think we ought to get on with it.

[The prepared statement of Mr. Skeen follows:]

PREPARED STATEMENT OF HON. JOE SKEEN

Thank you, Mr. Chairman.

I have been looking forward to these hearings because of my familiarity with the deteriorating conditions of our highways. The only people who travel more than Congressmen are traveling salesmen. And few Congressmen have longer distances to travel than I do in New Mexico. Deteriorating roads have been great for the 55 mph speed limit—everyone is afraid of ruining their cars.

The decade before us is a crucial one for our nation's highways. Reaching the end of their designed life time, thousands of miles of road and thousands of bridges will become dangerously unsafe, or actually unusable.

The problem has been obvious for years, but it wasn't until last December, under the Administration's strong support and direction, that the Congress finally acted. Beginning in fiscal year 1984, no less than 40 percent of funds apportioned to each state for transportation will be directed to the "Four R's": Resurfacing, Restoring, Rehabilitating, and Reconstructing existing highways. It makes little sense to build new roads that feed into a system deteriorating beyond use.

The issue, on the surface, appears simple: We simply have to rebuild and repair our roads. Dig below the surface just a bit, such as recent Congressional Budget Office study did, and a wide range of policy issues emerges. Perhaps even more important than the policy issues are the technical ones.

Not often discussed, the role of science and technology is key in the effective spending of the estimated billions of dollars that will be expended in the next 10 years. I look forward to hearing our witnesses during the 3 days of hearings in hopes that this point might be more fully developed and recognized by the Congress and the transportation community.

Thank you again, Mr. Chairman. Let's get started.

Mr. GLICKMAN. Thank you.

There are two panels. Our first panel is Thomas B. Deen, Executive Director of the Transportation Research Board at National Academy of Sciences/National Research Council; Dr. David Belle Isle, Project Director for the Department of Transportation Task Force on the President's Private Sector Survey on Cost Control; and William Butcher, Director of the Civil and Environmental Engineering Division of the National Science Foundation.

Your entire statements will appear in the record, gentlemen, so you may feel free to summarize as best you can. Sometimes when I say that people take longer summarizing than they do when they read the statements, but you take the time you need to get your message across.

What we ought to do is start with Mr. Deen and move to Dr. Belle Isle and then Dr. Butcher.

Mr. Deen.

STATEMENTS OF THOMAS B. DEEN, EXECUTIVE DIRECTOR, TRANSPORTATION RESEARCH BOARD, NATIONAL ACADEMY OF SCIENCES/NATIONAL RESEARCH COUNCIL; DAVID R. BELLE ISLE, PROJECT DIRECTOR, DEPARTMENT OF TRANSPORTATION TASK FORCE, PRESIDENT'S PRIVATE SECTOR SURVEY ON COST CONTROL; AND WILLIAM S. BUTCHER, DIRECTOR, CIVIL AND ENVIRONMENTAL ENGINEERING DIVISION, NATIONAL SCIENCE FOUNDATION

Mr. DEEN. Thank you, Mr. Chairman.

I am pleased to be here today and I would like to begin by commending these two subcommittees for looking into this matter given that we have now gotten some increased funds for our highway system in the Surface Transportation Assistance Act passed just a few months ago. It is important that we not overlook the importance of highway research activities.

I would like to begin by quickly mentioning something about the organization I am with. I am the Executive Director of the Transportation Research Board, a major unit of the National Research Council, which is the operating arm of the National Academies of Science and Engineering.

However my testimony today is my own. I am not speaking on behalf of TRB or the National Research Council but rather based on my own opinions from experiences I have had in TRB and 16 years in directing a private consulting firm in the transportation and engineering field in the United States and around the world.

I believe that highway research efforts in the United States have produced impressive results. As a nation we enjoy perhaps the finest and certainly the most comprehensive highway system in the world. When one recalls the primitive state of our knowledge in the 1920's and 1930's and compares it with today, it becomes clear that it simply would not have been possible to build the system we have in this country if research efforts had not been productive.

We are vastly more capable today in areas of payment design, safety features, traffic operations, planning methodology, bridge construction and preservation than we were in the past. As critical as our current maintenance and other highways needs are, they would even be greater were it not for these advances.

This knowledge has been gained without an establishment of a unified large research institution to select topics and execute all needed research. Rather, our forebearers decided, wisely I think, to manage and carry out research either within or as closely as possible to the operating agencies which must make use of the results.

Accordingly today highway research is funded not only by the Federal Government, but by most of the States, a number of turnpike authorities and a few of the larger counties and cities and also private sector suppliers. Research problem statements are generated by practicing professionals located throughout the industry so that the entire enterprise enjoys close links between practitioners and researchers. Studies directed to the problems are actually carried out within operating agencies, universities, consulting firms, and private laboratories. The entire process can fairly be characterized as very much a grassroots operation.

The backbone of the operation comes from the requirements originally found in the Hayden-Cartwright Act of 1934 which required that 1.5 percent of each State's Federal highway apportionment be used for planning and research activities. These funds, often called HPR funds, augmented in many cases with State funds, currently produce a State-operated and controlled research effort estimated at about $30 million annually.

In addition, the States, through AASHTO, pool about $5 million annually for research conducted by the national cooperative highway research program in the TRB. Research topics undertaken in NCHRP are selected by an AASHTO-sponsored committee of State representatives, a mechanism that insures that the program remains responsive to State needs.

Aside from these efforts, the Federal Highway Administration, FHWA, spends more than $20 million annually on highway research, most of it conducted by universities and consultants working under contract to FHWA.

It is difficult to get accurate numbers on highway research spending by other organizations. It is scattered throughout several agencies, various organizations, and academic institutions.

The scale of highway research has been declining in recent years. This decline can be seen on slide for the Federal level, which is a time series chart showing in constant dollars the total R&D funds in DOT which declined 38 percent in constant dollars, even though the entire program for the Department increased by 27 percent in this period.

The 50 States show a similar decline of about 40 percent in constant dollars in research spending over an 8-year period.

FHWA figures show that by 1979 only 15 percent of all planning and research funding—the HPR fund I described earlier—was spent on research, 85 percent was spent on planning. This low research proportion appears to continue into the 1980's.

In summary about $40 billion are spent by all levels of government, State, local, Federal, on highways each year and only about

$60 million plus or minus $5 million are spent on research or less than 0.15 percent. As seen in this chart our research spending as a proportion of total highway programs has declined for several years and since 1965 has dropped by 40 percent.

It is useful to put this low level of 0.15 percent into perspective by looking at the next slide which compares and shows what some private sector industries spend in various areas.

You can see from this slide that high R&D intensive industries whose new products come out in a continuing stream and that their survival depends on new products in future years. They spend anywhere from 5 to 10 percent of gross revenues on research typically.

Another group in the middle comprising the medium R&D intensive industries spent about 2 percent on research and the lowest group at the bottom spends about 0.8 percent.

As shown in the next slide the medium R&D group spends at a rate of 14 times the highway industry, and the lower group made up of food canning and tile products and some fairly low R&D intensive-type activities spends about 5 times as much.

The very lowest industry group within the lowest category, that is food and kindred products, spend 14 percent or about 3 times our rate.

Now, the next slide also shows how we compare with other advanced countries. The far right column is the percent of total spending that is spent for research in a group of different countries. We are next to the bottom.

Now, there are probably a variety of reasons why this has been taking place. We used to spend more. We spend less now for a variety of reasons, perhaps the most important difference however is that management motivation is different between the private and public sectors. Managers in high-tech industries can see clearly the relationship between R&D efforts and future profitability of their companies. In low-tech industries, this relationship is less dramatic but management nevertheless perceives that to underspend the competition is to risk the welfare of the firm.

Public sector managers on the other hand are generally not concerned about competition taking their business in the future. Further it is easier to make a good case for the budget each year if it can be shown there is little or no fat and fat often is defined by cost-conscious legislative bodies as any item not having immediate benefits, and research being a long-term effort suffers in such environment.

There are a variety of other reasons. I think it is important however to point out that there are nevertheless a number of highway managers in the United States who are very positive on research and some States have growing programs despite the overall declines. Texas and Virginia, for example, have big interests in these programs and the nationwide program of highway research continues to produce useful results in practice and I mention those in my testimony.

Even though the current decentralized process I described is appropriate for our main efforts the system nevertheless I think has some shortcomings. Perhaps the biggest of these is its apparent inability to focus large efforts on single problems, however deserving they might be.

Most projects emerge in units of $150,000 to $400,000 and projects larger than a half million dollars are very rare.

Yet some problems cannot be effectively attacked without mounting larger, more comprehensive efforts. While the vast majority of our research programs facing industry today can best be handled by this unfocused, decentralized approach, there are a few areas where these are inadequate. One of the problems is that of asphalt pavement methods and materials. Something like $10 billion a year will be spent for asphalt materials in place.

To put that in perspective, that is roughly 10 times the gross revenues of Amtrak, twice the gross revenues of the inner city bus industry, and about half the revenues of the commercial airline industry in this country.

It is a wonderful material, we are hooked on it and dependent on it. We would like it to have more durability, we would like if it would be more forgiving, not require such precision in its application. It gives us an occasional embarrassing failure and we would like it to have a bit more endurance.

We are not mounting a comprehensive effort to look at this kind of problem. We spend about $1 million a year in fragmented activities on asphalt research which is about 0.01 percent.

Mr. **Glickman**. We spend a million on total research into asphalt improvement?

Mr. **Deen**. That is correct. It is difficult to come up with a precise figure but it cannot be far off of that.

You can get any group of asphalt people in a room and they will debate what the problems with asphalt are and indeed whether these problems are increasing or decreasing. That by itself underscores the problem because it is suggestive that a $40 billion industry vital to the economy of the Nation, namely the highway industry, is without an effective mechanism to monitor and improve the material critical to its business.

Responding to this problem requires more than increase in research funding although that too is important. Equally important would be a focus on the problem of bringing together the skills ranging from materials scientists and chemists on one end to highway and pavement specialists at the other. Also required is a sustained level of effort in manpower, laboratory equipment, and facilities commensurate with potential payoff.

A 10-percent improvement in the average life of asphalt pavement would save us $1 billion annually within a few years. Spending 1 to 2 percent of that, $10 million to $20 million a year in a well-conceived program would not appear inappropriate although it is far in excess of our current efforts of about $1 million annually.

Asphalt is not alone. You can make an equally convincing statement about portland cement. We have a number of studies that cite this fact.

Other examples are use of salt for snow and ice removal, that is a cause of the large part of the $6 billion we spend for corrosion to vehicles, bridge decks and structures and environmental damage. Our efforts to find a noncorrosive deicer run half a million a year, and these are fragmented efforts.

Our knowledge of efficient lifecycle pavement management techniques is primitive although we probably will spend upward of $200 billion on pavement management in the next 20 years.

Another activity would be the possible use of advanced simulation technology to try to learn more about the relationship between geometric design of roadway elements and traffic safety.

These are a few that could be cited where we need to focus our efforts.

In conclusion, Mr. Chairman, the Nation is not keeping pace in highway research relative to other industries, to the highway research programs of other nations, the United States is simply not devoting adequate resources to this problem. If it is to capture its share of technological advances it needs to increase substantially research funds available and needs to concentrate some of these funds on areas of high potential payoff.

I cannot yet fill in the specifics of how to do this. I cannot specify precisely which topics have the highest priority, which organization should administer the funds or how much should be spent on research or how the cost of the program should be borne. I know the Federal Highway Administration and AASHTO are concerned about these problems and I hope a study now underway at TRB will be able to answer some of these questions in the next 6 months. I would be able to give you the answers at that time.

That concludes my prepared remarks and I will be pleased to respond to your questions.

[The prepared statement of Mr. Deen follows:]

PREPARED STATEMENT OF THOMAS B. DEEN

I am pleased to be with you today to discuss the nation's activities in highway research. I commend you on having the foresight to hold these hearings. As public and private interests involved in highways turn their attention to spending the urgently needed funds that the Congress made available in the Surface Transportation Assistance Act of 1982, it is important that we not overlook highway research activities. Existing highway research activities are spread across the many state, federal, county, and private agencies that build and maintain roads. Because of this close linkage between research and operations, current research activities respond effectively to the varied problems that arise regarding specific regions or products. But problem-by-problem research is not enough if highway activities are to advance as rapidly as they have in other industries. In my comments today, I will discuss four aspects of highway research:

- existing mechanisms and resources devoted to highway research;
- the adequacy of highway research;
- reasons for our low investment in research; and
- what is needed, in general terms, to make highway research more valuable.

Before I begin, however, I would like to introduce myself and my organization. My name is Thomas B. Deen. I am the Executive Director of the Transportation Research Board (TRB), a major unit of the National Research Council, the operating arm of the National Academies of Sciences and of Engineering. TRB was established in 1920 (then as the Highway Research Board) to provide a clearinghouse for research information between the states, universities and other institutions. Since that time the other transportation modes have become a part of TRB and today we are one of the few institutions concerned with the full range of transportation research; ensuring that the latest and best results of research are disseminated to the practicing professional, and improving the likelihood that each research effort exploits previous efforts. One of our major efforts is the administration of the National Cooperative Highway Research Program (NCHRP), which uses funds pooled by the states through the American Association of State Highway and Transportation Officials (AASHTO), to conduct research on selected highway problems identified by the states. TRB also executes selected research efforts for the federal government or others as requested.

However, my testimony and comments today are not on behalf of TRB or the NRC, but should be regarded as my own opinions, based on experience both in TRB and the 16 years I spent directing the activities of a diversified transportation consulting engineering firm working throughout the U.S. and in a number of foreign countries.

CURRENT MECHANISMS AND SPENDING

I believe that highway research efforts in the U.S. have produced impressive results. As a nation, we enjoy perhaps the finest and safest and certainly the most comprehensive highway system in the world. When one recalls the primitive state of our knowledge during the 1920s and 30s it becomes clear that it simply would not have been possible to develop our system to its current level if research efforts had not been productive. We are vastly more capable today in areas of pavement design, safety standards, traffic operations, maintenance procedures, planning methodology and bridge construction and preservation than in the past. As critical as our current maintenance and other highway needs are, they would even be greater were it not for those advances.

This knowledge base has been gained without the establishment of a unified large research institution to select topics and execute all needed research. Rather, our forbearers decided, wisely I think, to manage and carry out research either within or as closely as possible to the operating agencies which must make use of the results. Accordingly today highway research is funded not only by the federal government, but by most of the states, a number of turnpike authorities and a few of the larger counties and cities and also private sector suppliers. Research problem statements are generated by practicing professionals located throughout the industry so that the entire enterprise enjoys close links between practitioners and researchers. Studies directed to the problems are actually carried out within operating agencies, universities, consulting firms and private laboratories. The entire process can fairly be characterized as very much a "grass roots" operation.

The backbone of the operation comes from the requirements originally found in the Hayden-Cartwright Act of 1934 which required that 1.5% of each state's federal highway apportionment be used for planning and research activities. These funds, often called HPR funds, augmented in many cases with state funds, currently produce a state operated and controlled research effort estimated at about $30 million annually. In addition, the states, through AASHTO, pool about $5 million annually for research conducted by the National Cooperative Highway Research Program in the TRB. Research topics undertaken in NCHRP are selected by an AASHTO sponsored committee of state representatives, a mechanism that ensures that the program remains responsive to state needs.

Aside from these efforts, the Federal Highway Administration (FHWA) spends more than $20 million annually on highway research, most of it conducted by universities and consultants working under contract to FHWA. The Administration has just this year dedicated a new and extensive highway research laboratory located in suburban Washington.

It is difficult to get accurate numbers on highway research spending by other organizations. Research in major trade associations such as the Asphalt Institute, the Portland Cement Association and others has declined in recent years but perhaps $1-$2 million could be spent by such groups each year. Other suppliers (other than equipment and vehicle manufacturers) spend about $1 to $2 million. As the National Highway Traffic Safety Administration is mandated by Congress to direct primary attention to vehicles and users of the highways, a large portion of its research effort is focused on accident data collection and analysis, vehicle research, and the important areas of drunk driving countermeasures, occupant protection, pedestrian safety, and traffic law enforcement. A relatively small portion of its research budget can be deemed highway research. In addition, very small efforts can be found in the Departments of Defense, Agriculture and Interior. Thus, depending on definitions, we can identify a grand total in the order of $60-65 million being spent in each year on highway research.

ADEQUACY OF HIGHWAY RESEARCH

Despite the strong organizational network within which highway research is funded and conducted, and despite the impressive results achieved over the years, I believe that there is reason for concern about this important activity in the years to come. A significant part of the senior management within the states and federal government have expressed concern about whether research is being adequately managed. This concern is especially noted in the frequency of questions on whether research efforts are adequately coordinated or focused, and whether they are sufficiently related to policy. The Federal Highway Administrator took special notice of this problem in a speech to the AASHTO Policy Committee in Portsmouth, New Hampshire in June 1982. He recounted his efforts to refocus research funds on projects that were well conceived or appropriately related to current policy and asked AASHTO for advice on the proper federal and state role in managing the highway research program. This incident is only one of several which illustrate concern by management at both federal and state levels on this subject.

Furthermore, the scale of transportation research efforts has been in decline in recent years. At the federal level this decline can be seen in Figure 1. In 1980, the U.S. Department of Transportation spent about $395 million on research and development for all modes of transportation, or about 2% of its total $21 billion program (Figure 1). This represents a decline of 38% (constant dollars) in level of spending from 1972-80, even though the Department of Transportation's total program for all purposes increased by 27% during this period. Thus, federal spending on transportation research has declined significantly both in absolute terms and as a proportion of total spending.

The fifty states show a similar decline (40%) in the level of effort (constant dollars) spent for research over the past 8 years. All of the expenditures for the combined category of planning and research have held relatively constant (in current dollars). However, the research component has dropped significantly as planning efforts have grown, often in response to congressionally mandated planning requirements. FHWA figures show that by 1979 only 15% of all planning and research funding was spent on research, while 85% was spent for planning, which included traffic counting and road inventories. This low research proportion appears to be continuing into the 1980s.

About $40 billion are spent by all levels of government on highways each year and only about $60 million is spent on research, or less than 0.15%. As seen in Figure 2, our research spending as a proportion of the total highway program has been declining for several years and since 1965 has dropped by 40%.1/

Comparison to Other Industries

It is useful to put this low level of 0.15% into some perspective by comparing it to research efforts in other private sector industries.

1/ A few states, depending on federal HPR funds for their research activities, are finding their HPR moneys sharply declining, which makes it difficult to maintain their research efforts. This happens in those states which have completed their portions of the interstate system and thus have smaller federal apportionments.

Some industries in newly emerging fields where new products are coming out in a continuing stream and whose very survival depend on new products spend upward of 5-10% of their revenues on R&D. Included in this group are aircraft and missiles (11.5%), computers (11.7%), and communications equipment (6.3%) (Figure 3). Another group comprising medium R&D intensive industries spends about 2% of revenues, on the average, on research. Included in this group are motor vehicle equipment at 3.8%, rubber products at 1.9%, and nonelectrical machinery 2.2%. The lowest group of R&D intensive industries as a group spends only about 0.8% on research. Included in this group are stone and clay products, metal fabrication, lumber products, and food manufacturing--all mature industries where changing technology has a minimal impact. It's not clear which group is the most appropriate for comparison with the highway industry. The rapid changes we are currently undergoing from an emphasis on construction to one on maintenance and the big changes in the vehicles we serve (bigger trucks, smaller cars) suggest that our industry may not be as mature as one might initially suppose. Our heavy use of engineering talent also suggests a dependence on technology. In any case, the medium R&D group spends at a rate 14 times as high as the highway industry while the low R&D group spends on the average 5 times as much. The very lowest industry group identified (food and kindred products, textiles and apparel) spends 0.4% or almost 3 times our rate. (See Figure 4).

Nor do our research efforts compare well with other advanced countries. Figure 5 indicates that we fall well below most other efforts.

REASONS FOR OUR LOW INVESTMENT IN RESEARCH

There probably are a variety of forces at work that cause this low investment in research. Perhaps the most important is the difference in management motivation between the private and public sector. Managers in a high-tech industry can see very clearly the relationship between their R&D efforts and the future profitability of their companies. Their entire business 5 years hence may be made up of products coming from the R&D labs today. In low-tech industries the relationship is less dramatic, but management nevertheless perceives that to underspend the competition in R&D is to risk the future welfare of the firm. Under such conditions, it is not too difficult to convince one's Board of Directors to make adequate allocations for research. Public sector managers, on the other hand, often have opposite incentives. They are generally not concerned about competition taking away their business in the future. Further, it is much easier to make a good case for the budget if it can be shown that there is little or no "fat" in it. Often fat is defined by cost conscious legislative bodies as any item not having immediate benefits. Research, being a long-term, high risk effort, often suffers in such environments particularly when an aggregate reduction in overall spending is necessary.

Attention to research has also been preempted by other developments. Highway management has of necessity been compelled to spend disproportionate amounts of time on revenue measures in recent years. The decreasing yields of fuel taxes have caused unprecedented problems for highway managers and have distracted them from longer-range concerns such as personnel development and research.

Another important factor is industry fragmentation or decentralization. There are many participants--with 50 states, the District of Columbia, Puerto Rico, and more than 3,000 counties and 250 metropolitan areas, plus uncounted tollway, turnpike and toll bridge authorities, most of which have some road responsibilites. There is considerable evidence that fragmented industries tend to underspend on research compared to others and also data that indicate that there is a threshold level of agency or firm size required before research appears to begin to exercise a significant role. For example, a highway manager for a large county, while faced with a considerable array of researchable problems during a given year, does not feel he holds responsibilities sufficiently broad to launch the necessary research on a problem that extends far beyond his jurisidiction. The manager cannot spend very much money entrusted for local use to solve national problems.

Four Myths

Beyond all these factors, research seems to suffer from the acceptance of several myths that abound in the industry:

(1) There is a general feeling among many that there is not much imperative for further research because we know enough already. This attitude stems from the fact that we have just built an enormous highway system over the past several decades. If we know enough to build it, we must know enough to maintain it. Such simplistic notions are probably similar to those of our auto industry 5-10 years ago. After all, as a nation we had built more autos than anyone in the world, had been researching the gasoline engine for 50 years or more and surely knew more than anyone about production methods. While public sector highway management feels no threat from foreign competition, the error of that type of complacency is now obvious to us all.

(2) Among those who concede that our knowledge is incomplete there are many who feel that further research is not likely to be of much help. In part this is a self-fulfilling prophecy. Our research efforts have recently been so low and fragmented that progress can be seen only in very small increments rather than in significant breakthroughs. However, we are living in a period of unprecedented technological progress. Our ability to make significant progress in materials and processes when required has been amply demonstrated in our space program and several of our high tech industries. As I will note later, there is reason to believe that well directed efforts of sufficient scale could produce benefits to the highway industry as well.

(3) Some in highway management believe that there is little need for much research in the public sector because the private suppliers to the industry will provide most, if not all, the improvements necessary. While some suppliers do conduct significant and productive research programs, especially those in the traffic signs, paint, control systems and equipment areas, most private suppliers to the industry, many of which are small businesses, conduct little or no significant research. A large proportion of our highway dollars go to the purchase of cement, asphalt, and aggregates of various types. Discussion with representatives of these industries have indicated that there is little incentive for them to spend much on product improvement since specifications are well established and

competition consists mostly of low price and good service. Heavy investment in research towards product improvement would simply tend to raise costs in the short term. Public sector managers are understandably dubious when suppliers argue that they have a superior but more costly product, especially when superiority often means durability, a quality only measurable over time. This question--whether private suppliers have adequate incentive to perform highway research--is one that needs careful examination. Simply assuming that our private suppliers will do the required research may be largely wishful thinking.

(4) Finally, some transportation managers believe that the management of research is simply too difficult to make it much of a useful tool. The FHWA Administrator's concerns in this regard were noted earlier in this paper. Former Secretary of Transportation Drew Lewis was also often critical of transportation research as conducted over the past decade by some elements of DOT, citing a lack of relevance to problems actually facing the industry. Much of this type of critism is related to the advanced vehicle work sponsored in the past primarily by the Urban Mass Transportation Administration.2/

Often cited are the:

- Transbus Program aimed at designing a new urban transit bus ($28 million)
- Advanced Concept Train (ACT) Transit Rail Car ($27 million)
- Urban Tracked Air Cushion Vehicle ($17 million)
- Personal Rapid Transit Vehicle System ($65 million)

It is easy to second guess these projects after the fact, but this history is a reality that makes some in management reluctant to see research as a sufficiently safe investment to warrant expansion. However, it is important to keep this in perspective. During the early 70's many of our biggest private sector industries were also enamored by the prospect of application of high technology to urban transportation problems. Many of them including Ford, GM, Boeing, Rohr and Westinghouse invested large R&D sums in these efforts. They have since concluded that many of these efforts were misdirected and have turned their research attention elsewhere. By contrast, some of their public sector counterparts have concluded that transportation research is intrinsically wasteful.

Management of research does pose difficult problems, and is an often neglected function in the public sector. However, it would be unwise for us to underuse research simply because some efforts turn out unproductive or because we are not willing to make the efforts necessary to manage it properly.

Despite these problems and concerns, many, perhaps most, highway managers see the value of research. Indeed a few states (e.g., Texas and Virginia) have vigorous research programs that have increased in recent years; and, nationwide the research system continues to produce results useful in practice. Figure 6 is presented as only one of many examples of effective

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2/ UMTA has made a number of organizational and procedural changes in recent years to avoid these problems in the future. However, many transit managers are still dubious about the relevance of research partly as a result of this earlier period.

highway research conducted with relatively small budgets. However, it should be clear that these efforts have declined and, unless something alters existing trends, research can be expected to continue its decline, at least as a proportion of our total highway effort.

WHAT IS NEEDED

My remarks so far have cited the decline in research efforts and have suggested some reasons why it is occurring. But I do not think that all of this could be corrected simply by spending large sums of money. I believe that the evidence does suggest our efforts have been underfunded, and this needs correction. The recently passed Surface Transportation Assistance Act will increase somewhat the 1.5% HPR funds available. However, it is not clear how the states will elect to spend the added funds and therefore whether research efforts will increase.

I also have noted our decentralized approach to the funding and conduct of highway research and have further suggested that the process provides healthy linkages between researchers and practitioners. The satisfactory performance of this network over the past several decades makes it unwise to undertake any major alterations.

Even though the current process is appropriate for our main efforts, the system nevertheless has some shortcomings. Perhaps the biggest shortcoming is the apparent inability to focus large efforts on single problems however deserving. The process for selecting research projects usually involves the development of problem statements from operating units. These statements are screened by committees often representing the several functional areas or, in the case of pooled research efforts, the committee is often representative of various parts of the country. In either case, such committees are under budgetary pressure to spread the available moneys over a broad group of projects; otherwise, one large project would force all other activities to a halt. The result is that most projects emerge in units in the $150,000 to $400,000 range and projects larger than $500,000 are rare. Yet some problems cannot be effectively attacked without mounting larger, more comprehensive efforts. Even the FHWA, which conducts the most extensive research efforts within the industry, is under pressure in recent years to attack problems that will produce short-term results and to mount a comprehensive attack on a wide array of problems. Given funding limitations this has meant, in most cases, small projects in large numbers.

While the vast majority of the research problems facing the industry today can best be handled in our current unfocused decentralized approach, there are a few of our biggest problems where this may be inadequate. The following are presented as examples:

Asphalt

Asphalt is perhaps the material most vital to the nation's highway program. About $7 billion are spent annually, or about 18% of all road expenditures, for asphalt paving in place. This total, considering recent increases in federal and state funds available for roads, is likely to increase to $10 billion or more in just a few years. Most of our asphalt comes from oil refineries as a product of the refining process.

However, despite its importance, there are growing concerns that problems with our procurement and use of asphalt are large and perhaps on the increase. The data are not systematic, but scattered evidence of premature failure of asphalt paving continues to accumulate. While asphalt may be fairly predictable and reliable when used and applied with precision, this precision may be more than we can systematically muster in the field. Mix design, types of aggregates, temperature, humidity, methods and timing of compaction--all must be right for a given application. The whole process is relatively unforgiving of variation, sometimes resulting in unpredictable and occasionally embarrassing failures.

Evidence also suggests that the chemical properties of the basic asphaltic cement may be varying in ways that we cannot detect with our traditional and still currently used physical tests, but which nevertheless may be affecting the performance of the pavement in service. For many years there was a constancy in the source of crude oil and asphalt refining process in a given area of the country. Empirical physical specifications relating to penetration and viscosity developed during this period were adequate to ensure performance as a paving material. However, with the upheaval in the oil industry over the past decade, there are new changes in both crude stocks and the refining process which result in a degree of variability in asphalt chemistry previously unknown. This variability may well be affecting pavement performance in ways we don't understand.

In past decades when asphalt and portland cement producers saw themselves locked in competition for the construction of the interstate system, asphalt producers conducted research--some related to improving product performance and some towards assisting users in problem solving on specific applications. Incentives for product improvement appear diminished today as oil economics have been upended and asphalt appears to have a decided competitive edge when used for road restoration and maintenance. Today, some oil companies are doing research to reduce the amount of asphalt produced from a given barrel of crude oil because of the higher prices received for gasoline, fuel oil and other oil products. Some refineries have installed facilities required for using oil residuals for producing coke instead of asphalt. When this happens no asphalt is produced.3/

As all this is occurring, the decentralized research efforts of the highway sector have tended to respond by continuing to examine better ways to formulate pavement mixes, compaction and construction processes, additives and material recycling. While all this continues to be important, it may be insufficient and, in some cases, futile, if the basic material is nonconstant in ways that are currently undetectable. Improving asphalt is a multifaceted undertaking involving asphalt chemistry, testing processes, mix procedures, construction methods, training of personnel at all stages of the process, and systematic monitoring of pavement performance. Decentralization makes it difficult to obtain an overview of the problem and especially the dimensions of its various components. Thus while there is considerable evidence that the problems with asphalt are substantial as I have indicated, we do not really

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3/ None of this suggests anything perverse about management's motivations. Asphalt only produces about 4% of oil company revenues. Presumably, any rational management would give asphalt a very low priority.

know how serious the problem is or the importance of its various components, because such sweeping analyses are not within the scope of any existing institution. That statement by itself underscores the problem, however, for it suggests a $40 billion industry (the highway industry), vital to the nation's economy, but without an effective mechanism to monitor and improve a material critical to its business.

Responding to this problem requires more than simply an increase in research funding. Equally important would be a focus on the problem, a bringing together of the skills ranging from materials scientists and chemists at one end to highway engineers and pavement specialists at the other. Also required would be a sustained level of effort in manpower, laboratory equipment and facilities commensurate with potential payoffs. A 10% improvement in the life of the average asphalt pavement would mean savings of $1 billion annually in a few years. Spending 1-2% of that amount ($10-20 million) in a well conceived program of research would not appear inappropriate although far in excess of our current efforts estimated at less than $1 million annually.

Should a consensus on making such an effort emerge, questions of appropriate institutional mechanisms for funding and managing it immediately surface and may present problems as difficult as those in the asphalt itself.

Portland Cement

Asphalt is only one of several large-scale problems in the highway field where disproportionately small and/or under-focused research efforts may be observed. Our understanding of the basic chemical processes at play in our use of portland cement is primitive. A recent report by the National Research Council concluded that our spending on research on this vitally important and heavily used material was inappropriately small.4/ It also showed how other nations were moving ahead of us in this field. Highways consume only about 15% of cement production. Thus the fragmentation in cement use adds an additional element of complexity to the problem of response.

Other Opportunties

Our use of salt for snow and ice removal is the cause of a large part of the $6 billion annual cost we bear for corrosion of our vehicles, bridge decks and structures, and environmental damage. Yet our efforts to find a non-corrosive deicer, while continuing, currently run at about $500,000 annually or about .01% of potential payoff. Efforts here are also fragmented.

Our knowledge of efficient life-cycle pavement management techniques and of causes of pavement deterioration (e.g., traffic use vs. environmental effects) remains unacceptably primitive given the $200+ billion we will be investing in this process over the next two decades.

4/ National Reseach Council. National Materials Advisory Board. Committee on Status of Cement and Concrete R&D in the United States. NMAB Publication no. 361. The Status of Cement and Concrete R&D in the United States. Washington, D.C.: National Academy of Sciences, 1980.

Significant opportunities may exist to expand our knowledge of relationships between geometric designs of roadway elements and traffic safety by taking advantage of recent advancements in simulation technology.

Other examples could also be cited but these are sufficient to indicate that there may be a need for more focus and consolidation of our efforts on a few selected common problems deserving more effort and attention than they can achieve under our current approach. Highway management is examining this possibility in a current study underway at the Transportation Research Board. FHWA has funded a project called "The Strategic Transportation Research Study" specifically aimed at identifying such problems and recommending possible solutions. AASHTO has indicated they are looking to the study as a guide to future research efforts. It must be emphasized that the study steering committee has not yet developed its findings and recommendations. The point here is that these problems are currently getting intensive examination by highway management and findings should be out by year's end.

CONCLUSION

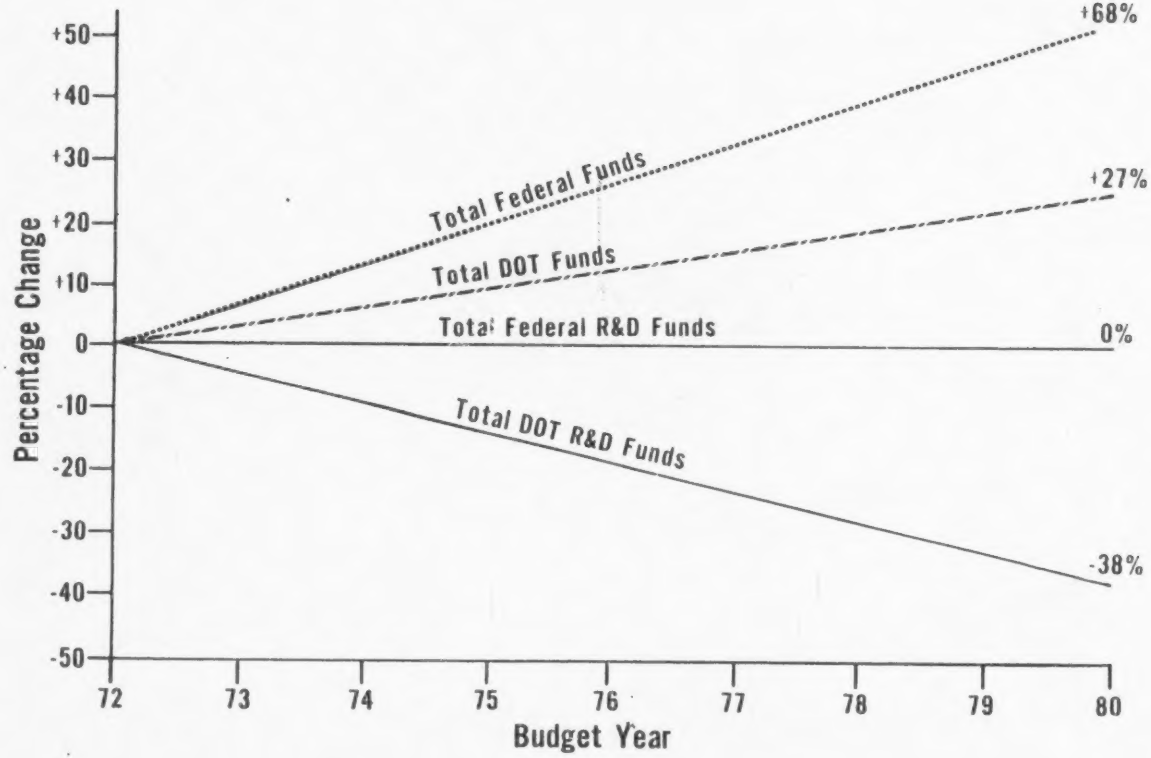
In conclusion, Mr. Chairman, the nation is not keeping pace in highway research. Relative to other industries and to the highway research programs of other nations, the United States simply is not devoting adequate resources to highway research. The infrastructure crisis of this past year may become a blueprint for the future unless the highway sector finds better ways to exploit the potential of new products and processes. Substantial increases in highway research funding are essential if we are to do this.

But simply increasing the funding for existing highway research programs (although this too is needed) will not effectively concentrate resources on the greatest opportunities. Existing research funds are dispersed across hundreds of decentralized units, each focusing on problems of local or regional importance. This is important and appropriate, because this is the only way to learn more about the enormous number of local and regional variations in paving materials, soil conditions, climate, terrain, and traffic conditions. But what this decentralized system cannot do is amass resources and concentrate them on key nationwide concerns, such as the performance of asphalt, which I discussed earlier. No existing organization has the resources or the mandate to do this. Spending more money on existing highway research programs will not by itself correct this shortcoming.

If the highway sector is to capture its share of technological advances, it needs to increase substantially the research funds available and it needs to concentrate some of these funds on areas with high payoff potential. I cannot yet fill in the specifics of how to do this--which are the high payoff areas, which organizations should administer the funds, how much should be spent on such research, or how the cost of the program should be borne. The FHWA and AASHTO are concerned about these problems and I hope that a study of this issue now underway at the Transportation Research Board will answer some of these questions during the next half year, and I will be able to give you more specific conclusions when this study is finished.

Mr. Chairman, that concludes my prepared remarks. I will be happy to answer any questions that you or members of the Committee might have.

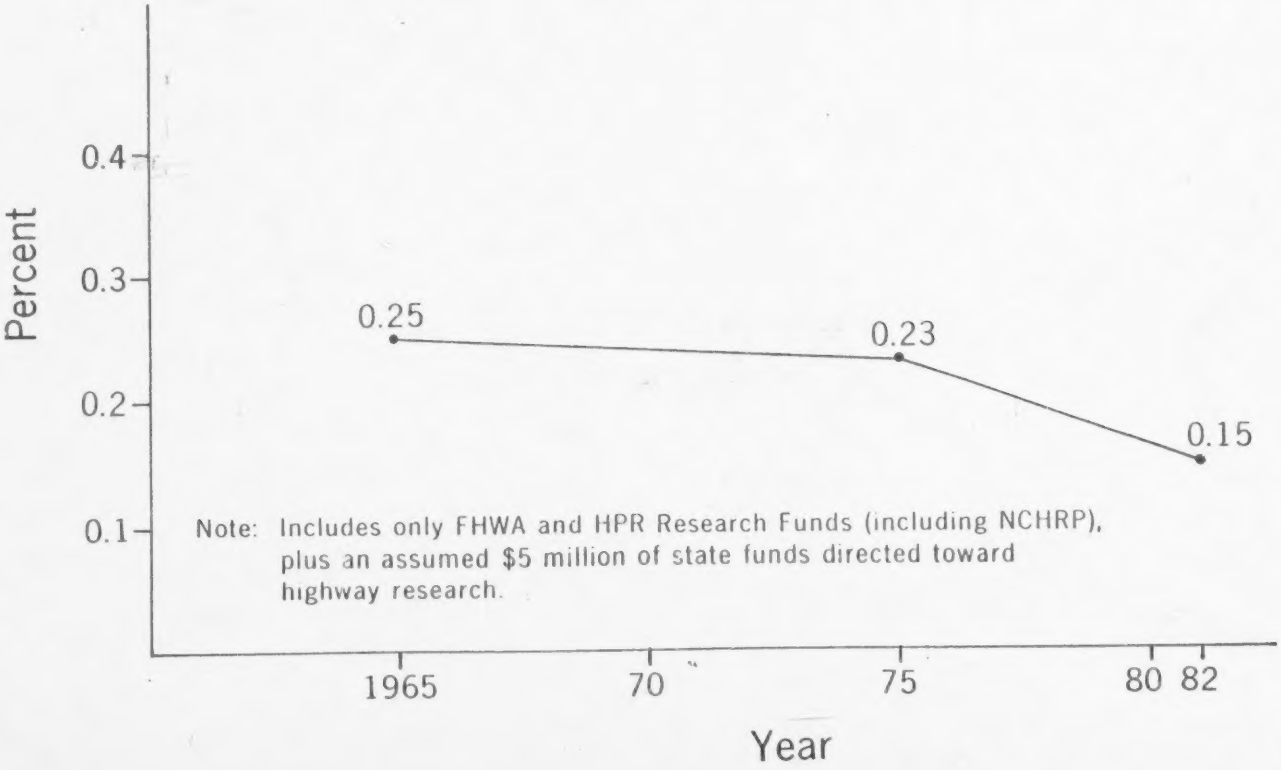
FIGURE 1



NOTE: Intermediate Years Not Plotted

FIGURE 2

HIGHWAY RESEARCH AS A PERCENTAGE OF TOTAL HIGHWAY PROGRAM EXPENDITURES



Note: Includes only FHWA and HPR Research Funds (including NCHRP), plus an assumed $5 million of state funds directed toward highway research.

FIGURE 3

R&D FUNDS AS A PERCENTAGE OF SALES

HIGH R&D INTENSIVE INDUSTRIES		
Office Computing, Accounting Machines	11.7	7.8
Aircraft and Missiles	11.5	
Electrical Equipment and Communications	6.3	
Professional and Scientific Investments	6.1	
Chemicals and Allied Products	3.5	
MEDIUM R&D INTENSIVE INDUSTRIES		
Motor Vehicles and Equipment	3.8	2.0
Nonelectrical Machinery	2.2	
Rubber Products	1.9	
Other Transportation Equipment	1.3	
Petroleum Refinery and Extraction	0.7	
LOW R&D INTENSIVE INDUSTRIES		
Stone, Clay, Glass Products	1.2	0.8
Fabricated Metal Products	1.1	
Paper and Allied Products	1.0	
Other Manufacturing Industries	0.7	
Lumber, Wood Products and Furniture	0.7	
Primary Metals	0.6	
Textiles and Apparel	0.4	
Food and Kindred Products	0.4	

FIGURE 4

R&D as a Percentage of Gross Revenues

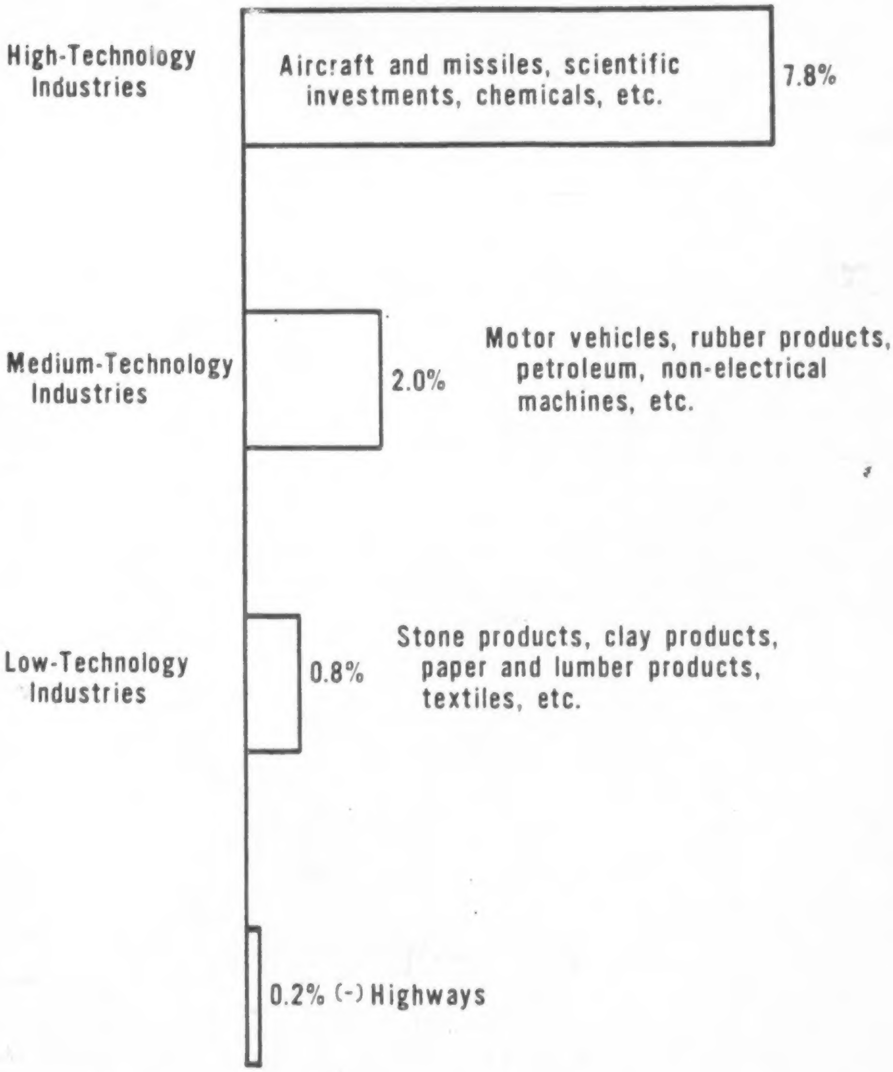


FIGURE 5

FOREIGN HIGHWAY RESEARCH PROGRAMS

COMPARED TO U.S.

Country	Highway Spending All Levels of Govt. (Millions of U.S. $) 1982	Highway Estimated Research Spending (Millions of U.S. $)	Research as Percent of Total Spending (%)
Sweden	955	30	3.14
United Kingdom	3,062	45	1.47
Australia	2,350	19	0.81
Federal Republic of Germany	9,800	20	0.20
United States	40,000	60	0.15
Japan	19,486	17	0.09

FIGURE 6

Research Pays Off

Kansas DOT Saves Its Bridges —and $1 Million Besides

What do you do when you discover that your "bridges may come falling down"? When annual inspections in Kansas uncovered cracks in some of the state's concrete bridges that could lead to failure, a research project was formulated to determine the cause and find a remedy. The cracks proved to be the result of shear, the remedy was post-reinforcement, and the application of the research effort paid off in savings of more than $1 million.

PROBLEM

Between 1955 and 1965, the Kansas Department of Transportation (KsDOT) built many bridges on its highway network by using two-girder continuous reinforced concrete construction. When inspections revealed shear cracks present in some girders that could result in failure, the KsDOT decided to investigate repair techniques rather than go the route of tearing down the bridges in question and building new ones. This approach was KsDOT's application of the "frontier" philosophy of repair, use up, wear out, make do, and innovate—and it worked! With a budget of $50,000 provided by KsDOT and the Federal Highway Administration through its Highway Planning and Research Fund, research began in 1976 on a repair technique called post-reinforcement.

SOLUTION

The post-reinforcement method was developed by KsDOT researchers and engineers Wayne Stratton, Roger Alexander, and Bill Nolting. It involves (a) locating and sealing all of the girder cracks with silicone rubber, (b) marking the girder centerline on the deck, (c) locating the transverse deck reinforcement, (d) vacuum drilling 45° holes that avoid the rebars, (e) pumping the holes and cracks full of epoxy, and (f) inserting reinforcing bars into the epoxy-filled holes. This process makes bridges stronger than when they were first built. Although the original design followed the 1957 AASHO Bridge Specifications, the shear-carrying capacity at certain points in the girders was as much as 36 percent below the 1981 AASHTO Specifications, but that of the repaired girder is 46 percent greater than the as-built condition and now exceeds the 1981 Specifications. Even greater strength is possible by closer spacing of the reinforcing bars.

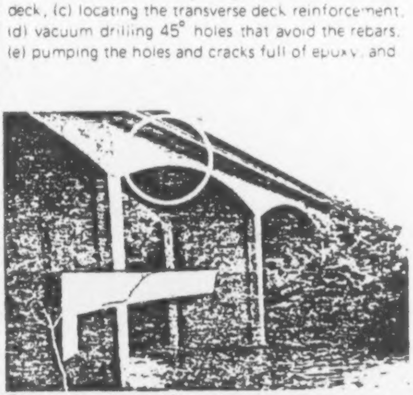


Diagram shows how reinforcing bars were placed to repair bridge girder circled in photo.

APPLICATION

During this study, 19 girder-halves were repaired under the supervision of the KsDOT researchers. After this work demonstrated the merit of post-reinforcement, a developmental phase (funded at less than $50,000) was initiated in 1980 to train bridge maintenance personnel and to continue refining the repair procedure. Another 11 girder-halves were repaired during this phase, and KsDOT engineers worked with industry to develop a durable, high-speed, vacuum drilling rig that would be capable of producing straight, small-diameter, dust-free holes in reinforced concrete to a depth of 8 or 9 ft. The equipment, which is highly maneuverable and able to drill holes at a 45° angle, was subsequently field tested and is now available for heavy-duty repair operations.

The repair method has been adopted by KsDOT as a standard procedure. Plans and specifications are available, and a contractor has successfully completed rehabilitation of two bridges that included post-reinforcement of the concrete girders.

BENEFIT

Both time and money were saved as a result of this research effort. A total of 30 girder-halves were repaired at an average cost of less than $2500 each. Removal and replacement would have cost about $40,000 for each girder-half—not including costs associated with construction detours and loss-of-service time. KsDOT calculated savings in excess of $1 million as a result. Not a bad return on an R&D investment of less than $100,000.

Kansas has more than 80 bridges on which the post-reinforcement method can be used. Thus, the major benefit of this effort is still to be realized. However, given the magnitude of bridge repair problems across the nation, the potential for savings through the application of this process in other states could reach many millions of dollars.

For further information, contact Carl Crumpton or F. Wayne Stratton, KsDOT, 2300 Van Buren Street, Topeka, KS 66611, telephone 913-296-7410.

From TRNews, January-February 1983, courtesy of the Transportation Research Board.

THOMAS B. DEEN

Mr. Deen is Executive Director of the Transportation Research Board having been appointed by the President of the National Academy of Sciences in June 1980. Prior to this he was Chairman and Executive Vice President of the firm of PRC Planning & Economics and President of Alan M. Voorhees & Associates, a division of PRC Planning and Economics. He was also senior advisor to larger and more complex transit and transportation studies conducted by the firm in such cities as Boston, Houston, Minneapolis-St. Paul, Atlanta, San Juan, and Buffalo. He is a graduate civil engineer, licensed in the states of Ohio, Tennessee, Massachusetts, Kentucky, Delaware, and California.

Mr. Deen graduated from the University of Kentucky and did graduate work at University of Chicago and Yale. He received the Pyke Johnson Award in 1976, which is given by the Transportation Research Board for the outstanding paper in the field of transportation systems planning and administration. He is a frequent lecturer at universities and professional symposia.

Mr. GLICKMAN. Thank you for a very thoughtful statement.

Our next witness is Dr. Belle Isle. You may proceed.

Dr. BELLE ISLE. Thank you.

It is a pleasure to be here and an honor.

Mr. GLICKMAN. What we will do is ask questions at the end of the panel, so we will hear the testimony first.

Dr. BELLE ISLE. I would first like to clarify the role I played and how it is I am here to testify. I was a member of the President's Private Sector Survey on Cost Control and specifically assigned to the Department of Transportation. Within that I worked on a specific study to look at R&D organization, planning, and spending within the Department of Transportation. My full-time employer is Martin Marietta Corp., which loaned me to the PPSS for a period of 6 months to serve on the task force.

I would like to give a brief background on some of the purposes of and premises of the task force.

The President directed the Private Sector Survey on Cost Control to look at five specific areas. One is identify opportunities for increased efficiency and reduce costs achievable by executive action or legislation; second, to determine areas where managerial accountability can be enhanced and administrative controls improved; third, suggest short- and long-term managerial operating improvements; fourth, specify areas where further study can be justified by potential savings; and finally to provide information on data relevant to governmental expenditures, indebtedness, and personnel management.

We were not to address the issue of governmental policy. We were to address the issue of management and implementation of policy.

In our study of the Department of Transportation there were 12 members of my task force and we proceeded to get involved in 22 separate pursuits of inquiry. The one that I was specifically the manager of was R&D. In that regard, there were some conclusions as a result of that study that I would like to share with you and then go on to talk about the methods by which we feel R&D can be even more effective within the Department of Transportation.

The first conclusion was that the cost of research investment may exceed the benefits. On the whole much of the past R&D expenditures in the DOT are difficult to justify in terms of results. For example, some $750 million spent by UMTA for R&D has produced little change in the way people move about in American cities or contributed much in new productivity.

That is not to say that development focused R&D is inappropriate to transportation; technology innovation and productivity. However, DOT-sponsored development projects are not producing useful significant advances. Our concern is that the quality of R&D suffers from inadequately specifying the desired outcomes and implementing programs to monitor and achieve them.

The second conclusion is that the research planning and coordination process requires change. The goal-setting process for R&D in the Department is not adequate. Given the primary focus on developmental R&D programs coordination was likely not to be perceived as valuable in the past.

However, there can be significant value coordinating long-term research in the Department.

Transportation safety is one such opportunity area for departmentwide coordination. A technology most pertinent to safety innovation is electronic data systems. The national air space plan mentioned earlier is based on a national commitment to air traffic safety and control.

The technical innovations required to meet the challenges for air safety by the 1990's certainly have potential applicability in urban transit rail and highway safety, such as vehicle monitoring computers and electronic communication.

In order to seize these opportunities, a coordination mechanism is called for. The Department of Transportation must take the lead to identify other significant technological needs and goals for transportation safety and then to coordinate the appropriate government, private sector, and university resources to achieve them.

The third conclusion is that research management and budgeting processes require change. Lack of a management system has detracted from development of long-term perspective and overall strategic purpose for R&D initiatives in DOT. Thus congressional intent and DOT policies in support of it either have not been implemented or if implemented have not achieved their objective.

DOT can and should develop an R&D management and resource system to clarify strategic transportation goals and assure resources are appropriately targeted and controlled.

Fourth, research policy and organization issues must be addressed. Though congressional statutes and DOT policies clearly encourage the private sector to invest in R&D programs to apply innovative technologies and to continue strong support for basic knowledge and research; there is limited evidence that these objectives are implemented or achieved.

While DOT is supposed to quote "promote and undertake development, collection and dissemination of technological, statistical, economic and other information relevant to domestic and international transportation," it is not evident how this information is provided to and utilized by the private sector, university, and Government laboratories to encourage joint R&D initiatives.

Mr. GLICKMAN. Dr. Belle Isle, I want to hold you there. These are the second bells on a motion to approve the journal. We will be running back and forth to vote because the House is now in session. Let's hold it now and we will come back in 10 minutes.

[Recess.]

Mr. CARNEY [presiding]. The meeting will resume.

We ask you to pardon the interruption for having to go vote on the floor of the House. Mr. Belle Isle, you are still in the middle of your testimony.

Please continue.

Dr. BELLE ISLE. Thank you, Mr. Chairman.

Let me go back and recap this final conclusion which is on research policy and organizational issues.

The final note to make here is the DOT research organizations are too decentralized to achieve the value of coordinated research initiatives with other Government agencies and nongovernment organizations.

I would like to go through now the series of recommendations that have been made to address these conclusions. The first recommendation is the Department of Transportation through the Office of the Secretary should create an entity responsible for R&D policy goal setting and monitoring.

Specifically in this area the overall DOT entity responsible for R&D policy should be created to accomplish the following: Define the goals and mission for DOT R&D and clarify the role that R&D must play; recommend to the Secretary policies and overall R&D goals and opportunities; and serve as coordinator between various DOT R&D managers within the operating administrations and the transportation systems center.

With this work arrangement the strategic issues problems and opportunities surrounding transportation systems advances could be identified.

Advisory groups, representatives of various State and local transportation system operators, scientists and experts would be brought together to identify transportation innovations, technology, and productivity problems which they believe are essential to solve and to provide support to the Secretary in analyzing, developing and monitoring implementing policy.

The second recommendation is to create a new DOT R&D organization structure and management review process.

Within this recommendaton we suggest that there be created within the Office of the Secretary a transportation technology, innovation, and productivity entity.

Within this organization they would reorganize the research and development activities currently housed within the Research and Special Programs Administration and establish a new policymaking role with funding capability to support secretarial studies.

Within this recommendation the transportation systems center would become an integrator of external resources—university and Government and industrial—for identifying and accomplishing basic technological initiatives in the transportation field.

Our final recommendation is to posture and encourage potential joint efforts in transportation research and development.

The process of encouraging the private sector to assume responsibility for Federal research objectives involves the following recommended steps:

That advisory groups identified earlier work to identify product needs and perform premarket analysis.

The facilitators provide an interface with the private sector concerning potential product opportunities.

Private investors either assume the R&D based on market potential and expectations of return on investment or reject the ideas as lacking potential.

The private R&D activities lead through usual stages to commercialization; the U.S. Government and Government grantees as well as others provide the market.

A rejection of an R&D idea by investors leads to reconsideration by advisory groups who then revise and refer their final recommendations. Products that are considered of an overriding national interest could be cycled through OMB for consideration.

OMB acceptance of the advisors recommendation leads to Government funding.

A rejection of an R&D budget request by OMB is a final decision, subject to the will of Congress.

Rejection of a project idea may be appealed to the President.

Within this we have recommended a management process and I believe you have a copy of the diagram which is in my study, exhibit 10-4. If you just refer, please, to that diagram I think you can see the types of relationships we are encouraging here.

Essentially what we would like to encourage the Department of Transportation to do is to do a strategic planning scan of the company transportation needs and then coordinate with other resources in R&D where you have university labs, industry labs, and private sector labs who could in joint ventures pursue technology essential to innovation, and productivity.

With private sector commitment and a sense that there is a market potential for a product, they would be willing to carry some of the burden of R&D funding and remove some of the burden on the taxpayers.

Essentially what we see in terms of this exhibit is that the product of these efforts would be quickly made available to the marketplace to serve needs that are essential and certainly in the area of highway construction and material. This is an appropriate example.

The last exhibit which in my study was exhibit 13-1, what we tried to illustrate is how a research outlook that takes a strategic long-term focus could provide for an integration that would work across the various modes of transportation. Currently within the Department of Transportation the R&D budgeting process is a bottoms up within each operating mode process and there is very little direction and guidance from the Office of the Secretary that encourages an integrated long-term strategy around R&D expenditures.

To the extent that you fragment R&D dollars you are not able to achieve critical mass technology exploration and development. Our concern is that with the fragmentation of dollars and the spending levels at approximately $300 to $350 million annually, we are not seeing efforts that produce transportation, innovation, productivity, and technology advancements.

Thank you.

[The prepared statement of Dr. Belle Isle follows:]

DEPARTMENT OF TRANSPORTATION

RESEARCH AND DEVELOPMENT
WITHIN THE DEPARTMENT OF TRANSPORTATION

ISSUE AND RECOMMENDATION SUMMARY NO. TRANS 1

A. ISSUE AND SAVINGS

Are Department of Transportation (DOT) research and development (R&D) programs and expenditures being managed effectively, in keeping with Congressional mandates and departmental missions and goals pertaining to critical issues facing transportation in the United States? Study indicates that the organization and management of R&D in DOT can be greatly improved. Our recommendations result in initial savings of up to 30 percent of annual R&D appropriations ($73 million for FY 1982). Although future savings depend on policy-guided research goals and priorities determined in the Office of the Secretary (OST), it is possible by following the recommendations to generate additional savings in the second and third years of implementation through R&D manpower reductions.

B. BACKGROUND

The DOT Act of 1966 (P.L. 89-670) established the statutory mandate for R&D in DOT to stimulate technological advances in transportation and provide general leadership in identifying and solving transportation problems. In carrying out the act's purposes , the Secretary is charged with disseminating technological information on domestic and international transportation and promoting and undertaking R&D relating to transportation.

The R&D essentially supports the DOT's mission to develop policies and programs conducive to safe, efficient, and convenient transportation at the lowest cost. Among the guidelines for R&D policies are four relating to budgeting. They call for fiscal restraint, sound economic criteria, encouragement of private investment, and continued strong support for basic, "advancement-of-knowledge" types of research.

Current R&D is undertaken to stimulate technological advances in services and facilities provided outside the DOT (in private industry and parts of the public sector other than DOT); create a basis for sound public policy and regulation in the areas of safety, fuel economy, and standard time zones; improve the effectiveness of federal grants; and support such DOT operational missions as the Coast Guard's search and rescue mission.

Research is sponsored by operating administrations and various Office of the Secretary organizations through Congressional authorizations.

The operating administrations sponsoring R&D are: the Federal Aviation Administration, Federal Railroad Administration, National Highway Traffic Safety Administration, U.S. Coast Guard, Federal Highway Administration, Urban Mass Transportation Administration, Maritime Administration, and the Research and Special Programs Administration (RSPA). (Exhibit 2 provides summaries of research areas for each administration.)

Research sponsored through the Office of the Secretary is primarily focused on policy analysis and review. The Assistant Secretary for Policy and International Affairs is the primary research sponsor.

The overall DOT budget authority for research declined 38 percent for the eight-year period from 1972 to 1980. The decline from 1981 to 1982 was 29 percent to a level of $243.6 million. This represented approximately 1.2 percent of DOT's total budget authority. The Fiscal Year 1982 appropriations were 98.6 percent to operating administrations with 1.4 percent to the Office of the Secretary (see Exhibit 3). There were 2,200 budgeted R&D positions for Fiscal Year 1982, down 12.5 percent from 2,515 in Fiscal Year 1981 (see Exhibit 4).

Transportation Systems Center

Within the Research and Special Programs Administration is the Transportation Systems Center (TSC). TSC is the DOT multimodal systems research analysis and development organization supporting the high-priority technology and economic analysis needs of the Secretary and operating administrations.

TSC was deployed from a NASA electronics research center to a transportation facility in 1970. It currently has about 200 varied transportation projects involving 485 federal employees in Cambridge, Massachusetts.

TSC operates through a working capital fund, a mechanism for transferring funds from the Office of the Secretary, operating administrations, and outside agencies to carry out individual projects. A general working agreement provides an agreed-upon upper funding limit of obligational authority for TSC along with a general statement of work to be performed. Project plan agreements establish scope of work, amount of labor, level of contractual support, and milestones for the project.

In Fiscal Year 1982, TSC received $54.7 million from DOT sponsors for research activities. The Federal Aviation Administration and the Urban Mass Transit Administration together accounted for 56 percent of TSC 1982 funding (see Exhibit 5). Sixty percent of the total funding to TSC was spent on in-house labor and operations (see Exhibit 6).

The nature of TSC's skill mix has changed dramatically over the past six years. Exhibit 7 illustrates how the engineering skill base of TSC was reduced by 32 percent from 1976 to 1982, while operations research and analysis skills increased by a factor of 2.6 during the same period. This shift in skill mix of TSC reflects the changing nature of the types of research projects that DOT sponsors are funding (see Exhibit 8).

C. METHODOLOGY

This study focuses on whether the current level of investment in research funding is commensurate with the benefits derived from the research that is conducted. It introduces innovative alternative funding sources for priority research in transportation product technology and productivity improvements.

The scope of our analysis covers the management of the research process, the budgeting system, the organization structures for research, and the related staffing level.

One task force member was assigned to assess R&D in DOT, its operating administrations, and the OST.

The methodology employed included performance of the following tasks:

- Interviews with DOT officials from the Office of the Secretary and the operating administrations.
- Review of various DOT policies, internal memoranda, and studies on research and development (see, for example, Exhibit 9).
- Review of other government agency research and development organizations.
- Examination of Department of Transportation concepts for involving the private sector in federally identified R&D (i.e, limited partnerships for research and development). (See Exhibit 10.)
- Examination of a sample of successful and unsuccessful DOT research projects.
- Review of Congressional legislation and mandates, and reports regarding research and development.
- Review of the literature on private sector research and development strategies.
- Interviews with senior consultants with expertise in R&D strategy formulation and planning: Peter Bower, Vice President, Management Analysis Center, Inc.; Robert Sterns, Management Technologies, Inc.; Gifford Pinchot, President, New Directions, Inc.; William Young, Vice President, BDM Corporation; Dr. Judith Selvidge, Assistant Vice President, BDM Corporation.
- Interviews with university and industry research laboratory directors and senior scientists: Dr. Kent Bowen, Director, Material Sciences Lab at M.I.T.; Mark Paich, MIT Systems Dynamics Group; Dr. Draper, Senior Scientist, Draper Labs, and Dr. Bert Westwood, Director, Martin Marietta Corporate Lab.
- Consultation with the PPSS Task Forces on Research and Development and Privatization.

D. FINDINGS

1. Planning for DOT Research and Development in the Transportation Sector

The study that resulted in a policy statement stresses the need for remedial action in the transportation sector, since this sector accounts for roughly 50 percent of the petroleum consumed in the nation but produces only 10 percent of our GNP and 15 percent of our exports. Since approximately 50 percent of our petroleum is imported, the transportation sector contributes heavily to the drawdown of the balance of payments. The study envisaged the problem as amenable to new R&D solutions, both technological and nontechnological.

The cause for concern and the need for remedial action in the transportation sector are further indicated in the following examples:

- Productivity is lagging in the transportation industry.
- Many segments of the nation's highway system are deteriorating, repairs are lagging, and the traditional petroleum-based products and materials used for repair are escalating in price.
- The automobile industry has suffered a dramatic erosion of domestic and export sales in the face of foreign competition, creating far-reaching economic dislocations throughout American industry.
- The passenger aircraft industry is being challenged in long- and short-haul areas.
- The bus manufacturing and urban transit rail car industry faces an uncertain future despite growing needs for local and intercity surface transportation other than the automobile.
- The domestic shipbuilding industry and American flagships face foreign competition with declining subsidies and loan guarantees.

- Venture capital firms are hesitant to invest in long-term basic research and product development essential to transportation advancements.

2. DOT Responsibility for Research Program Results

Despite the substantial commitment of dollars to research, we found it difficult to relate research results to specific DOT goals and policy.

The operational emphasis of research programs has produced insignificant results in terms of applicable innovation in transportation technology and products. The following examples are illustrative:

- The Morgantown Personal Rapid Transit Program, a $140-million expenditure resulting in a system that no other community has indicated an interest in replicating.

- The Trans-bus Program, a $10-million expenditure resulting in no product.

- Act-1 Program, a $25-million expenditure with no usable product at its completion.

A current example of a good strategic plan focused on a significant long-term commitment to technological innovation is the National Airspace Plan sponsored by the Federal Aviation Administration. The (NAS) plan is estimated to be a seven-year, $10 billion Congressional commitment toward meeting future national needs for air traffic control and safety. Very early it was identified as a desirable goal and supported by the secretary and congress which passed a separate appropriation to achieve the goal. The plan calls for significant involvement of the private sector and other government agencies in accomplishing its objectives.

As the implementation plan gains momentum the monitoring activity for the Secretary will rise in importance to assure achievement of goals within resources available and the time table envisioned.

We learned that numerous factors account for the lack of similar long-range R&D commitments and strategic plans for advancing transportation technology:

- R&D is at the present time modally oriented and is not integrated with Secretarial goals and long-term missions.
- R&D is not monitored by an entity concerned with implementing the Secretary's goals.
- Appointed senior DOT officials are insufficiently involved in framing R&D priorities to assure that programs are consistent with transportation system policies and goals.

As a result:

- The private sector does not have the opportunity to incorporate long-range, strategic, transportation technology advances into their plans for R&D capital programs and innovative products.
- University R&D laboratories are confronted by short-term horizons and the annual reprioritization of R&D funds. Thus, the creative abilities at university labs are lost to transportation because their time horizion over looks more than a couple of years.

3. Research Management and Budget Process

The responsibility for research management and budgeting is decentralized and delegated to research directors in each of the operating administrations.

After reviewing the current organization and management of R&D within DOT, it becomes apparent that there is no overall management and budgeting process for R&D programs. Each operating administration prepares an annual R&D budget that reflects its respective operational goals and needs. These budgets are not managed to assure that transportation research expenditures and outcomes achieve overall Department of Transportation goals. (See Exhibits 3 and 4.)

The Department does exercise an oversight function for acquisition including those involving R&D, through the Transportation Systems Acquisitions Review Council (TSARC) process. The members of TSARC are the Deputy Secretary, the General Counsel and the Assistant Secretaries, with the Deputy Secretary residing. TSARC reviews all acquisitioning, including those involving R&D, that total estimated expenditures of $20 million or more or which involves estimated expenditures for R&D of $5 million or more over a period of three years. Staff review of technical aspects of R&D projucts is delegated to the Office of Programs and Evaluation in the Office of the Assistant Secretary for Budget and Programs. Waiver of the TSARC review process can be granted in certain circumstances.

In analyzing the research budget for appropriations and manpower ceilings, it is apparent that these research resources were reduced by 29 percent and 13 percent, respectively. This trend is consistent with a National Science Foundation eight-year trend report which indicated a 38% decline in R&D appropriations (See Exhibit 11).

Transportation Systems Center's budget which peaked at about $58 million and 700 people is down to about $54 million and 500 people in Fiscal Year 1982.

A number of knowledgeable people in DOT and elsewhere have expressed concerns about the consequences of this pattern of decline.

In 1972, DOT's R&D obligations were approximately $351 million. In 1982, they were $151 million in constant dollars which represents a decrease of approximately 57 percent over ten years. DOT's R&D obligations for these years were as follows:

YEAR	$ MILLIONS
1972	351
1973	311
1974	370
1975	292
1976	339
1977	372
1978	372
1979	350
1980	374
1981	420
1982	329

The decline in DOT R&D over the last ten years was due to a variety of causes. The most fundamental and underlying factor was a gradual shift in the basic philosophy and attitude toward the use of R&D in the Department. In the earlier years, R&D was considered as a primary solution to many of the transportation problems ranging from institutional and financial to political. Emphasis was given to developing a range of advanced technology systems and subsystems along with a broadening of the R&D knowledge base to provide a spectrum of R&D options for the future. There was a recognition of transportation problems that transcended R&D responsibilities and resources of any one mode and some programs were initiated to address them.

Over the last several years, emphasis shifted toward near-term operational, regulatory and grant-in-aid programs. There was a realization that R&D could not solve all the institutional, financial, and political transportation problems and that the private sector, modified by the marketplace, should assume a stronger role in transportation technology development. As a result, the R&D share of the total department budget has declined with a movement away from capital-intensive and advanced technology systems as well as a decrease in transmodal R&D. Priority has been given to short-term and lower cost R&D programs. Other characteristics include:

- a shift from hardware to software R&D (socio-economic systems analysis cost benefit studies, etc.)
- limitation on demonstration programs
- very few new initiatives

Examples of some of the programs that no longer receive strong funding support as a result of the change in R&D emphasis include:

Basic/Advanced Research:

- non-contact suspension technology
- linear induction motors (LIM) and magnetic levitation (Mag Lev) propulsion systems

- satellite research
- alternative fuels
- underground construction
- research safety vehicles (RSV)

Capital-Intensive Systems

- tracked air cushion vehicles (TACV & UTACV)
- advanced personnel rapid transit (PRT's)
- advanced air traffic movement systems (AATMS)
- rail electrification

Transmodal R&D

- integrated freight terminals
- urban modal interchanges
- transmodal construction
- data systems research
- some interrelated generic research in such areas as noise, energy, safety and radionavigation

The impact of reduced and fragmented R&D expenditures on the technical quality, relevance, and value of program substances must be reviewed in the light of future objectives.

Without a research management system, it is most difficult to appropriately allocate and control R&D research resources to match the unique character of R&D project categories, i.e., extending current product lives, launching new products, and citing new technological architectures.

4. Research Organization and Policy

The Transportation Systems Center (TSC) within the Research and Special Programs Administration does not have a real charter to develop department-wide R&D policy, to advise the Secretary, or to exercise R&D oversight. Thus DOT lacks a top-level R&D policy official.

The 1982 appropriation hearings of the House Appropriations Subcommittee has expressed the strong view that DOT lacks an R&D policy that provides guidance to operation administrations. The Deputy Secretary in a special FY 1982 spring review emphasized the vulnerability of R&D budgets and the urgent need for a strategy to make the most of reduced R&D funds for the future.

A recently formed Research Coordination Council representing each operating administration, the TSC, and the Office of the Secretary is attempting to address the department's needs for R&D policy evaluation and technology coordination.

E. CONCLUSIONS

1. Cost of Research Investment May Exceed the Benefits

On the whole, much of the past R&D expenditures are difficult to justify in terms of results. For example, some $750 million spent by UMTA for R&D has produced little change in the way people move about in American cities or contributed much in new productivity. That is not to say that development-focused R&D is inappropriate to transportation, technology, innovation, and productivity. However, DOT-sponsored development projects are not producing useful, significant advances. Our concern is that the quality of R&D suffers from inadequately specifying the desired outcomes and implementing programs to monitor and achieve them.

2. Research Planning and Coordination Process Requires Change

The goal setting process for R&D in the department is not adequate.

Given the primary focus on developmental R&D programs, coordination was likely not to be perceived as valuable in the past. However, there can be significant value to coordinating long-term research in the department.

Transportation safety is one such opportunity area for department-wide coordination. A technology most pertinent to safety innovation is electronic data systems. The NAS Plan mentioned earlier is based on a national commitment to air traffic safety and control. The technical innovations required to meet the challenges for air safety by the 1990's certainly could have potential applicability in urban transit, rail, and highway safety, such as vehicle monitoring computers and electronic communication. In order to seize these opportunities a coordination mechanism is called for.

The Department of Transportation must take the lead to identify other significant technological needs and goals for transportation safety and to then coordinate the appropriate government, private sector, and university resources to achieve them.

3. Research Management and Budgeting Processes Require Change

Lack of a management system has detracted from the development of a long-term perspective and overall strategic purpose for R&D initiatives in DOT. Thus, Congressional intent and DOT policies in support of it either have not been implemented or, if implemented, have not achieved their objective.

The Department of Transportation can and should develop an R&D resource management system to clarify strategic transportation goals and assure that resources are appropriately targeted and controlled.

4. Research Policy and Organization Issues Must Be Addressed

Though Congressional statutes and DOT policies clearly encourage the private sector to invest in R&D programs, to apply innovative technologies, and to continue strong support for basic knowledge research, (as noted previously on Pages 4-8), there is limited evidence that these policy objectives are being implemented or achieved.

And while DOT is supposed to "promote and undertake development, collection, and dissemination of technological, statistical, economic and other information relevant to domestic and international transportation," it is not evident how this information is provided to and utilized by private sector, university, information relevant to domestic and international transportation," it is not evident how this information is provided to and utilized by private sector, university, and government laboratories to encourage joint R&D initiatives.

The DOT research organizations are too decentralized to achieve the value of coordinated research initiatives with other government agencies and nongovernment organizations.

F. RECOMMENDATIONS

1. The Department of Transportation, Through the Office Of The Secretary, Should Create an Entity Responsible for R&D Policy and Goal-Setting, and Monitoring (TRANS 1-1)

Specifically, an overall DOT entity responsible for R&D policy should be created to accomplish the following:

(1) Define the goals and mission for DOT R&D and clarify the role that R&D must play.

(2) Recommended to the Secretary policies and overall R&D goals and opportunities.

(3) Serve as a coordinator between various DOT R&D managers within the operating administrations and the Transportation Systems Center. With this collaborative work arrangement the strategic issues, problems, and opportunities surrounding transportation systems advances could be identified.

(4) bring together advisory groups representatives of various state and local transportation system operators, scientists, and experts to identify transportation innovations, technology, and productivity problems which they believe one essential to solve.

(5) provide support to the Secretary in analyzing, developing, monitoring and implementing policy.

(6) provide a base of dialogue and communication with the private sector and universities in terms of transportation R&D and manufacturing issues and opportunities.

(7) monitor the process of implementing secretarial R&D goals

(8) Serve as "FACILITATORS" to encourage private sector investment in identified R&D opportunities.

(9) institute a strategic human resources planning and review process to assure that there are adequate personnel available to focus and guide the department's R&D efforts.

(9) stimulate relationships with the federal government's various R&D organizations in order to coordinate parallel efforts and enhance technological innovation within transportation.

2. Create a New DOT R&D Organization Structure and Management Review Process (TRANS 1-2)

This recommendation can generate a total R&D cost savings and avoidance of a magnitude in the tens of millions of dollars per annum.

(1) Create within the Office of the Secretary a Transportation Technology, Innovation, and Productivity (TTIP) entity (see Exhibit 12).

(2) Under the new TTIP reorganize the research and development activities currently housed within the Research and Special Programs Administration (RSPA) and establish a new policy-making role with funding capability to support Secretarial studies. (A separate DOT task force issue recommends the creation of a new Safety Administration to provide an umbrella for the non-R&D activities of RSPA).

(3) Identify an individual to head this TTIP entity and determine the appropriate reporting relationship to the Secretary.

(4) The Transportation Systems Center becomes the integrator of external resources (university, government, and industrial) for

identifying and accomplishing basic technological initiatives in the transportation field. This would fulfill the facilitator's role identified in Exhibit 10.

Additionally, TSC continues its current support activities as needed in support of the department.

(5) In order to determine the potential contribution of existing personnel to this new organizational entity review all R&D personnel currently employed by the various operating administrations and the Transportation Systems Center. Exhibit 4 is a short history of the Department of Transportation's R&D budget positions. After analyzing R&D manpower levels, we think it is realistic to expect an overall reduction in required manpower in future years of this new R&D strategy. The criteria to be used in reducing staff would be based on the mission and functions of the newly established TTIP. Therefore, some people currently in place would either be shifted to operational support roles within modes or identified as surplus.

(6) Contract for a study to generate R&D program planning and implementation criteria, to assess program objectives against strategic R&D goals of the department. It is assumed that some projects sponsored by the various modal administrations will not adhere to DOT strategic R&D criteria that would be developed. (Potential cost savings and avoidance from this recommendation of 15 percent of total R&D budget would be approximately $36.5 million.)

(7) Establish an effort to facilitate the assumption of DOT R&D by private investors. The mission of the TTIP Facilitators is to determine whether the private sector can be encouraged through incentives to invest private R&D dollars in government-identified R&D projects.

Exhibit 10 addresses one of several mechanisms available to encourage assumption of R&D by private investors. Limited research partnerships and the implications for federal research and development are discussed in this exhibit. This approach makes it essential to identify strategic goals in order to provide the private sector with planning information to encourage them to develop R&D initiatives consistent with Secretarial goals. The goal is to encourage privatization of R&D efforts to reduce government expenditures for R&D.

Exhibit 10 also illustrates the system of relationships that would encourage, among other devices, research and development limited partnerships. Our proposal envisions an organizational scheme that requires the establishment of a Department of Transportation strategic R&D entity. This entity would serve as a catalyst to attract investors for specified programs. Significant immediate budget savings would be achieved in the first year by privatizing all possible projects now funded by DOT and by cancelling all R&D projects for which no reasonable market potential exists. (Estimated savings potential of $36.5 million)

(8) Establish within each operating administration R&D group "intra-transportation entrepreneurs" (Intrapreneurs). R&D intrapreneurs would provide leadership to and be responsible for indentifying specific R&D opportunity areas. Each intrapreneur's role is to establish a plan, resembling the private sector entrepreneur's business plan.

In the private sector, the business plan is the sum total of the entrepreneur's idea and plan for acquiring the resources essential to achieving the plan. It usually includes a product/service idea, a market forecast, a statement of the need for capital and human resources, and strategies for introducing the product or service to the marketplace. The business plan becomes the entrepreneur's tool to seek venture capital.

The transportation intrapreneur would identify R&D opportunities and indicate its potential market and require capital, technological, and human resources. This plan would provide a prospectus for government, private sector, industry and university investors, and other stakeholders.

(9) Institute a Research Outlook, a planning tool, to focus the ongoing R&D programs of Secretarial objectives.

The purpose of this document is to identify to all interested parties, inside and outside government, the opportunities that exist for new transportation products For it, each modal R&D group would prepare a synthesis of its various programs and specify how program results address the objectives of both the sponsoring unit and the department as a whole. Research Outlook would cover the following topics:

- Future transportation trends, projections, and concerns.
- Continuing and future approaches to transportation advances.
- Scientific and technological bases needed to support these actions, including a discussion of the state of the art and deficiencies in knowledge.
- Research milestones and decision points for funding over the life of research programs.
- Existing or proposed collaborators from industry, private sector think tanks, universities, and other government labs.

The Office of the Secretary TTIP Director would be responsible for coordinating the development of the Research Outlook for the Secretary. The various Outlook strategies developed by operating administration R&D groups would be used to prepare integrated DOT Outlook chapters. The Outlook, in turn, would influence subsequent strategy revisions for modal and OST R&D efforts. As information guides subsequent planning (as shown in Exhibit 13), R&D plans are refined and made more specific. Later, results of department R&D activities and operations are reviewed to help prepare the following year's Outlook.

3. Posture and Encourage Potential Joint Efforts in Transportation Research And Development (TRANS 1-3)

The process of encouraging the private sector to assume responsibility for federal research objectives involves the following recommended steps:

(1) The advisory groups identify potential product needs and perform pre-market analysis (See page 4 of Exhibit 10)

(2) The facilitators provide an interface with the private sector concerning potential product opportunities.

(3) The private investors either assume the research and development based on market potential and expectations of return on investment or reject the ideas as lacking potential.

(4) The private R&D activities lead through usual stages to commercialization; the United States Government and government grantees as well as others provide the market.

(5) A rejection of an R&D idea by investors leads to reconsideration by advisory groups who then revision and refer their final recommendation. Products that are considered of an overiding national interest could be cycled through OMB for consideration.

(6) OMB acceptance of the advisors recommendation leads to government funding.

(7) A rejection of the R&D budget request by OMB is a final decision (subject to the will of congress).

(8) Rejection of a project idea may be appealed to the President.

G. SAVINGS AND IMPACT ANALYSIS

DOT research funding could be reduced by as much as $73 million in the first year. The reduction is an estimate based on the assumption that expenditures for non critical and/or privatized R&D projects can be eliminated.

Additionally, research staff can be reduced in the second and third years assuming aggressive implementation of R&D program screening and the privatization concept. Projected costs for the TRANS 1-2(6) and (7) R&D criteria development study would be $.5 million. (See Exhibit 14.)

H. IMPLEMENTATION STEPS

1. TRANS 1-1: Immediately, the Secretary should establish an entity responsible for R&D policy, goal setting and monitoring. Utilization by the secretary of an R&D goal-setting/implementation monitoring/facilitating entity will:

   - assist operating administrations in calibrating their goals to the secretary's
   - coordinate with the budget office concerning issues related to goals, funding, and other subjects
   - assist the Secretary in giving clear R&D policy guidance to the Budget Office of DOT
   - assume lead role in the TSARC process
   - assume chair role for the Research Coordination Council

2. TRANS 1-2: The Secretary should delegate to the TTIP official responsibility to reorganize and manage the initiatives outlined in this recommendation. Implementation should be completed by the beginning of FY 1984.

3. TRANS 1-3: The Secretary and TTIP official should initiate efforts, (during FY 1983) to work through advisory groups and facilitators to implement the privatization concept. This would be an on-going process, and be the responsibility of the TTIP official.

EXHIBIT I-1(1)

Department of Transportation
Office of the Secretary
Washington, D.C.

ORDER

DOT 4600.5A

3-29-74

SUBJECT: COST SHARING ON RESEARCH GRANTS

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1. PURPOSE. This order provides guidelines for implementing Federal Management Circular (FMC) 73-3, "Cost sharing on research supported by Federal agencies". The purpose is to encourage the use of cost sharing in research grants and to issue guidance concerning the amount of cost sharing that is appropriate.

2. CANCELLATION. DOT 4600.5, COST SHARING AND RESEARCH GRANTS, of 7-1-71.

3. BACKGROUND.

   a. FMC 73-3 replaces and rescinds Office of Management and Budget (OMB) Circular A-100. It requires Federal agencies to encourage cost sharing in all research that they sponsor, whether or not cost sharing is required by statute. The circular also provides guidance for determining the appropriate amount of cost sharing.

   b. The guidelines set forth in the circular must be applied to all research grants awarded or extended with additional funds.

4. POLICY. Cost sharing shall be considered before awarding any research grant. Where the decision is to use cost sharing, the guidelines listed in the circular shall serve as the basis for determining the grantee's cost share. Cost sharing (matching requirements) required by statute will continue to be administered in accordance with existing procedures prescribed by the operating elements of the Department.

5. RESPONSIBILITY. Each element in the Department administering research grants shall issue procedures to implement FMC 73-3. These procedures shall require that the reason for not using cost sharing be documented and retained in the grant file whenever the technique is not employed.

DISTRIBUTION: All Secretarial Offices
All Operating Administrations
National Transportation Safety Board
(info)

OPI: Office of Installations & Logistics

EXHIBIT I-1(2)

DOT 4600.5A
3-29-74

6. IMPLEMENTATION. Copies of the procedures are to be forwarded to the Office of Installations & Logistics (TAD-60) within 60 days after the date of this order.

FOR THE SECRETARY OF TRANSPORTATION:

William S. Heffelfinger
Assistant Secretary
Administration

EXHIBIT I-2(1)

General program areas for R&D Sponsors:

- COAST GUARD R & D efforts are directed toward its operating missions involving search and rescue systems, aids to navigation, commercial shipping and recreational boating safety, environmental protection, port safety and security, and icebreaking technology.

- The FEDERAL AVIATION ADMINISTRATION'S programs consist of efforts to improve the safety, performance, and productivity of the national aviation system and to increase the system's capacity to meet future traffic demands. Aviation research and development is directed toward increased effectiveness of air traffic controllers and pilots as well as toward environmental protection.

- The FEDERAL HIGHWAY ADMINISTRATION'S R & D program includes research in highways, safety, and demonstration projects and specialized research for the Bureau of Motor Carrier Safety to improve both safety and performance along the highways.

- The FEDERAL RAILROAD ADMINISTRATION conducts research in the area of rail safety, economics, technology, and policy research, focusing on near and intermediate-term conventional rail problems. .

- The NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION, through its Motor Vehicle and Traffic Safety Programs, focuses R & D on the safety of motor vehicles on the highway, fuel economy, and accident and data analysis.
- The URBAN MASS TRANSPORTATION ADMINISTRATION conducts R & D under Section Six of the Urban Mass Transportation Act, emphasizing, for example, improved safety and performance and reduced life-cycle costs of conventional mass transit systems, high payoff/risk automated systems, central city revitalization, and accessibility to transit for elderly and handicapped citizens.
- The RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION performs R & D in support of the Secretary, the operating administrations, and its own missions, with attention to intermodal and transmodal issues such as intermodal terminals, transportation use of energy, and hazardous materials transport and pipeline safety.
- The OFFICE OF THE SECRETARY supports the Secretary with policy analysis and overall guidance with respect to departmental R & D goals and objectives.

EXHIBIT I-3(1)

DOT R & D Budget
Budget Authority
($ in 000's)

	FY 1981 Appropriation	FY 1982 Appropriation	FY 1983 Administration Request
FHWA - BA	$ 9,740	$ 7,100	$ 8,520
-New Limitation	(21,545)	(16,397)	(19,067)
NHTSA	52,222	38,267	45,285
FRA	50,000	30,000	17,000
UMTA	65,500	51,600	45,000
FAA	106,155	80,597	133,500
USCG	25,000	18,000	15,000
MarAd	13,800	8,491	16,800
RSPA	10,741	6,203	5,826
OST	9,749	3,350	7,800
TOTAL BUDGET AUTHORITY	$342,907	$243,608	$294,731
FHWA New Limitation	(21,545)	(16,397)	(19,067)

EXHIBIT I-4(1)

DOT R & D Budget
Positions

	FY 1981 Manpower Ceilings	FY 1982 Manpower Ceilings	FY 1983 Request
FHWA	209	163	163
NHTSA	203	178	176
FRA	159	117	30
UMTA	126	96	93
FAA	875	861	845
USCG - Mil.	(112)	(112)	(67)
Civ.	112	24	24
MarAd	34	32	32
RSPA	643	581	558
OST	42	36	36
Total Civilian	2,403	2,088	1,957
Military	112	112	67
TOTAL	2,515	2,200	2,024

EXHIBIT I-5(1)

SOURCE OF FY'82 FUNDS
(MILLIONS OF DOLLARS)

	RSPA	OST	USCG	FAA	FHWA	NHTSA	FRA	UMTA	OTHER
FUNDS FOR R&D PROJECTS	1.8	-	1.1	1.3	0.3	5.8	4.0	16.5	0.4
FUNDS FOR NON R&D PROJECTS	0.3	1.1	5.4	10.4	0.6	0.2	0.8	2.4	2.3
TOTALS	2.1	1.1	6.5	11.7	0.9	6.0	4.8	18.9	2.7

R&D FUNDS	31.2 (57%)
NON R&D FUNDS	23.5 (43%)
FY'82 FUNDING TOTAL	54.7
WORK IN PROCESS	14.7
TOTAL FUNDS	69.4

EXHIBIT I-6(1)

USE OF FUNDS
FISCAL YEAR 1982

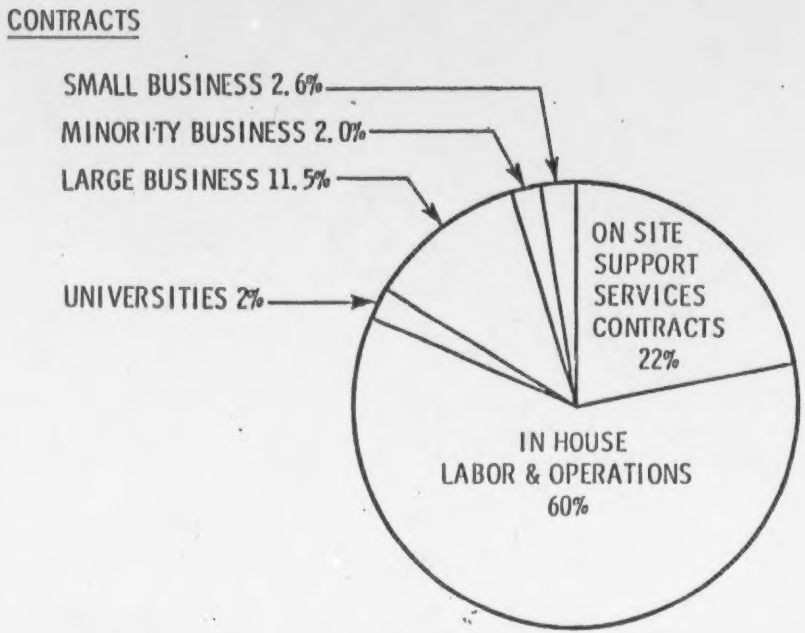
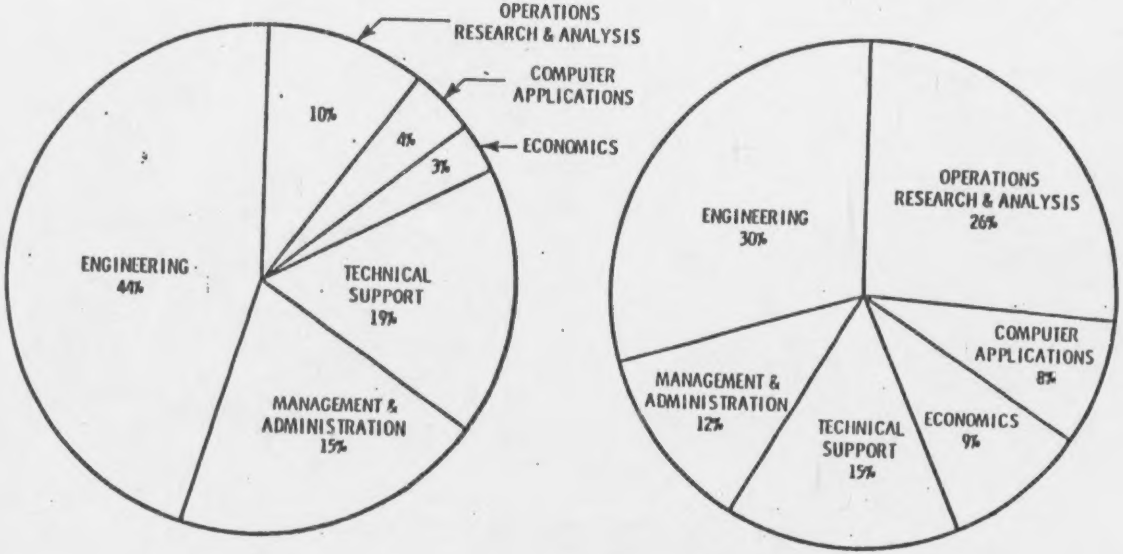


EXHIBIT I-7(1)

TSC'S SKILL MIX



FY 76

FY 82

EXHIBIT I-8(1)

DOT'S EVOLVING ROLE IN RESEARCH AND TECHNOLOGY

1970-73	1974-80	1981-
● SYSTEMS ENGINEERING	● SYSTEMS ENGINEERING	● ENGINEERING ANALYSIS
● HARDWARE DEVELOPMENT	● HARDWARE DEVELOPMENT	
● TECHNOLOGY ASSESSMENT	● TECHNOLOGY ASSESSMENT	● TECHNOLOGY ASSESSMENT
	● ECONOMIC ANALYSIS	● ECONOMIC ANALYSIS
	● POLICY OPTIONS EVALUATION	● POLICY OPTIONS EVALUATION
	● TECHNOLOGY SHARING	● TECHNICAL ASSISTANCE
		● INDUSTRY ANALYSIS
		● STRATEGIC PLANNING ANALYSIS
		● INTERACTIVE COMPUTER APPLICATIONS
(ENGINEERING)	(MULTI-DISCIPLINARY)	(DECISION AND OPERATIONAL SUPPORT)

EXHIBIT I-9(1)

STRATEGIC PLANNING AND GROUP'S REPORT ON RESEARCH AND DEVELOPMENT

Issue

Since the inception : DOT, the Department's R&D program has been the lump sum of the individual operating administrations' technical needs and internal objectives. Because OST never developed a process of reviewing and prioritizing its R&D, DOT's projects are selected and managed by the modes. The overall R&D management process at the Departmental level is considered by the R&D community to be poor to non-existent. With a better management process, DOT could have a better quality and more effective R&D program for the same money.

Discussion

In 1980, the White House Office of Science and Technology Policy concluded that DOT suffered management and policy problems. A DOT-wide task force was commissioned by the Secretary in July 1980 to review DOT's program. The study, which included on-site discussions with the leading R&D and management officials at NASA, DOE, DOD, DOI and DOC, found that DOT alone did not have some form of Departmental advisor or R&D management structure. Since then, there has been no change in DOT's R&D management structure and practices which might possibly alter that conclusion.

Operational Activities. R&D supports operational programs, through design of special equipment for air traffic control in FAA, or development of hull design for the USCG.

Safety Activities. R&D is used to support regulatory development such as automotive design, aircraft interior flammability, highway safety construction standards, etc.

Regulatory Standards. R&D is used to support regulatory standards development such as FAA's noise and medical research, USCG ship design standards, etc.

Industry Support. In some instances, DOT performs research in support of an industry such as FRA's track geometry research, FAA's aircraft design, UMTA's service and methods R&D, etc.

Although each of the above categories represents a valid area of research, currently DOT does not consciously segregate its research into these categories. Also, DOT does not prioritize its R&D among categories. In the past, it has been left to the operating administrations to decide what constitutes a "good" R&D program.

In the absence of a Departmental management process, it is next to impossible for the Department to assess the quality and need for its R&D projects, or to determine what R&D approach is appropriate. One example of

EXHIBIT I-9(2)

how the operating administrations approach R&D differently includes the issue of inhouse vs. contractor research. FAA, has the largest inhouse R&D capability with almost 1,200 employees dedicated to research. FAA has approximately one employee per $85,000 research dollars. NHTSA and UMTA by contrast have one R&D employee per $311,000 and $1.1 million respectively. Although some of disparity between the two is attributable to the type of research (i.e., operational vs. regulatory) or technology orientation (hard science vs. sort science) that is not an entirely satisfactory explanation. For example, in NASA there is one inhouse R&D employee per $290,000; this suggests FAA is excessively reliant on an inhouse R&D staff.

Also related to DOT's lack of R&D focus, the Department has been unable to resolve the issue what to do with the Transportation Systems Center. Although TSC is considered a valuable resource, it is not certain that DOT would today create a TSC if one did not already exist. The operating administrations each view TSC differently. For example, UMTA and NHTSA use TSC as extensions of their own R&D staffs; FHWA and USCG hardly use TSC. Some operating administrations simply use TSC's capabilities to contract and obligate R&D funds. A review of TSC workload would find a mixed level of R&D priorities.

Because of the lack of past OST R&D management policy and process, DOT's R&D program area offers the potential for significant cost and staffing savings. Issues which need to be addressed and resolved include: how large and how many personnel should DOT dedicate to R&D? What should be the goals of DOT's research? What should be TSC's role in the future?

Options. There are a multiplicity of R&D options to improve DOT's R&D programs. These range from development of a policy statement to possible consolidation of all DOT's R&D programs. Following is a brief outline of some options:

- Issue an R&D policy statement and establish an R&D prioritization process.
- Establish a technology advisor to the Secretary position (temporary or permanent) to assess DOT's R&D program, and to recommend changes. (Note: In response to the R&D task force findings, the Office of Transportation Research and Technology was established in the immediate Office of the Secretary to provide policy oversight to DOT's R&D programs and to advise the Secretary on technological issues. This office is currently unstaffed.)
- Commission an outside study by R&D experts to assess each of the operating administrations approach to R&D.
- Consolidate all DOT R&D programs or all DOT R&D facilities under a single head to establish some uniformity and consistency to DOT's approach to R&D.

EXHIBIT I-9(3)

Conclusion

DOT's problem in R&D extends beyond the lack of a policy statement, rather it is the manefestation of a lack of understanding of how to approach R&D. DOT needs to either internally or by contract examine its R&D to determine how it should approach the future. The fact that DOT has studied R&D many times in the past without meaningful result suggests that perhaps an outside, respected view is needed.

Recommendation

The Secretary commission an R&D review to determine what actions should be taken in DOT's program. This study could be performed:

- By a small group comprised of experts familiar with Federal R&D and users familiar DOT's R&D products, or
- An internal study team led by a non-DOT recognized expert on Federal R&D.

The study should give an unbiased assessment of DOT's R&D program based on at least three separate assumptions.

(1) If DOT were to perform only the most essential R&D using the fewest possible Federal employees.

(2) If DOT were to perform only essential R&D using the ideal number of Federal employees.

(3) If DOT were to perform R&D appropriate to the Federal role.

The study should also address what mechanisms are necessary in order for DOT to get control of its R&D program and keep it on a meaningful track in the future.

EXHIBIT I-9(4)

TRANSPORTATION SYSTEMS CENTER

STATEMENT OF ISSUE:

If the decision were made to reposition TSC from its current location in RSPA, how should DOT handle TSC? Should TSC:

(1) Continue to provide research and analysis support to the modes and OST, on a request basis, with funding provided from sponsor appropriations;

(a) reporting to the Deputy Secretary or,

(b) reporting to a Modal Administration;

(2) Conduct a "Departmental" research and analysis program, funded under a single TPR&D appropriation, under the direction of the Deputy Secretary (this option is the organizational element to a central R&D policy and program, referenced in R&D paper);

(3) Be reduced to a "housing" for modal staff, by assigning current TSC personnel directly to the appropriate modes;

(4) Be converted to a private-sector corporation that would market services to DOT, other government agencies, and industry.

What are the organization, staffing, and reporting issues in these and other options that should be considered in the FY-1983/84 time period?

DISCUSSION:

TSC has, since its conversion from a NASA electronic support facility to a DOT technical staff, been servicing Departmental needs on a requested basis financed through a working capital fund provided from modal R&D and OST, TPR&D appropriations. Over the past decade, its priorities have shifted from hardware-oriented R&D to analytical support services, including socio-economic research, operations research, systems analysis, and technology assessment and information development. Its services are now largely concentrated in those programs which have not developed their own large R&D staffs, e.g., UMTA and FRA.

TSC has developed a competent multi-disciplinary staff who take on jobs as a technical consultant, drawing heavily on the Boston area academic community, and developing a sense of professional and technical credibility which would be difficult to maintain in Washington.

The issue is that RSPA may not be the appropriate institutional setting in the future, and may not be now chartered to manage TSC effectively. Lacking a clear overall R&D policy, the Department may well be advised to continue status quo.

OPTIONS AND IMPACTS:

1a. TSC continue current operating mode, reporting to Deputy Secretary

PROS:

- Would be simple to implement
- Would generate least controversy of any option

EXHIBIT I-9(5)

CONS:

- Would exacerbate TSC's reputation for "uncontrollability" among modal sponsors
- Might be perceived as increasing the size of OST

1b. TSC continue current operating mode, reporting to a Modal Administrator

PROS:

- Would be simple to implement
- Would enhance responsiveness to needs of parent mode

CONS:

- Would create perception among non-parent modes as "second-class" sponsors
- Center of gravity between parent mode and TSC might be unclear, as it is in RSPA

2. Make TSC an independent Departmental research and analysis unit reporting to the Deputy Secretary

PROS:

- Would increase innovation and creativity in the TSC program
- Would provide enhanced credibility among the scientific community to TSC and its work product
- Would provide the Secretary with an independent source of advice and expertise on technical issues.

CONS:

- Would deprive Modal Administrations of valuable source of direct technical support
- Would reduce "real-world" perspective in TSC program management
- Might create adversarial relationship between TSC and modes
- Would be more difficult to secure appropriations to support TSC program
- Might be perceived as increasing the size of OST

EXHIBIT I-9(6)

3. Reduce TSC to "housing" for modal staff

PROS:

- Would reduce layering and increase accountability
- Would increase managerial flexibility for Modal Administrators

CONS:

- Would eliminate synergism and economies of scale
- Would sacrifice professional credibility attendant to TSC's current institutional identity
- Would be politically controversial

4. Convert TSC to a private-sector corporation

PROS:

- Would reduce the size of the DOT work force
- Would provide valuable capability to transportation industry
- Would send strong positive political signals vis-a-vis Administration attitudes toward government/private sector roles

CONS:

- Would reduce TSC responsiveness to DOT needs
- Would be difficult (maybe impossible) to implement politically and practically

EXHIBIT I-10(1)

Limited Research Partnerships Implications for Federal Research and Development

General

The limited research partnership is a new means for financing research and development activities that has been gaining wide acceptance. Such partnerships offer tax benefits to the investor in exchange for acceptance of risks normally attached to research and development activities. The attractiveness of this investment medium suggests that many research and development activities heretofore sponsored by the federal government could, under certain circumstances, be funded by the private sector.

If a substantial portion of the research currently sponsored by the federal government could be undertaken by the private sector, many advantages would accrue: These include

1. reduction of the federal budget,
2. potential increase in the amount of capital devoted to research and development, and
3. creation of conditions conducive to the assumption by the private sector of additional activities of the federal government.

Government versus Private Sector Financing

A distinction may be made between military research and civilian-oriented research. The military perceives and satisfies its own needs, performing or sponsoring its own research and acquiring the products of this research. For civilian-oriented research the line of demarcation between research atiyities normally sponsored by the federal government and research activities suitable for private sector sponsorship is more difficult to draw. Generally, government-sponsored research is intended in some way to benefit the public welfare. Privately-sponsored research requires only the perception of a suitable market and a reasonable expectation of overcoming risks. Government-sponsored research is often aimed at supplying some vital need and may or may not depend on a market large enough to justify research and development costs. Cost versus benefit analysis usually plays some role. However the standards for justifying government sponsorship, and for attracting private funds for research generally differ.

EXHIBIT I-10(2)

Government funding of civilian-oriented research is usually justified by a combination of public need and unwillingness (or inability) of the private sector to fund this research. This unwillingness may stem from high technical risk, uncertainty of successful marketing even if the research is successful, high costs uncompensated by sufficient perceived recovery of costs, insufficient certainty of recovering costs, or some combination of these factors.

The limited research partnership through provision of tax benefits in exchange for acceptance of the risks of research, changes the balance between risk and rate of return on investment. Limited research partnerships generally undertake projects having a high degree of inherent risk, which may make the projects unsuitable for normal equity financing. Since higher risks can be accepted, the possibility exists that some research, now supported by the government because of the risk involved, could be undertaken by the private sector.

The relationship between risk and rate of return on investment may be further offset through government provision of incentives for successfully carried out research (prizes). However, it should be recognized that the risk can-not be entirely negated by the government, since the acceptance of risk is the basis of the favorable tax treatment.

A discussion of the basic features of the limited research partnership is contained in the Appendix.

Department of Commerce Program

The Department of Commerce (DOC) has embarked on a program to encourage the use of limited research partnerships. The DOC program has several elements as follows:

1. Reduction of policy barriers through provision of anti-trust exemptions and clarification of tax policy.
2. Provision of strategic information including information on foreign patents and information developed from federal research expenditures.
3. Education on the merits of limited research partnerships and on the relevant tax laws.

EXHIBIT I-10(3)

A Plan for Encouraging Assumption of Government Research Projects by the Private Sector

A plan to encouranye the private sector to undertake research currently funded by the private sector could be undertaken and would involve the following entities. The relationships between the various entities are illustrated in Figure 1.

-Advisory groups having access to technical or market information. Such groups would make available expertise from the Urban Mass Transportion Administration, Federal Aviation Administration, Federal Railroad Administration, Department of Defense and other departments and agencies.

-Federal Grantees having access to federal and local funds for the satisfaction of local needs.

-Research and Development Entities including government laboratories, industrial and other private laboratories and university laboratories.

-Facilitators interfacing between advisory groups and general partners.

-General Partners to undertake the management for responsibilities the research.

-Limited Partners to provide the necessary financing.

-Manufacturers to produce the products of the research under license

The following government activities would aid and encourage the private sector to assume research activities normally undertaken by the government.

1. Making known an interest is having certain research performed by the private sector.
2. Performance of preliminary market analysis.
3. Creation of advisory groups to:

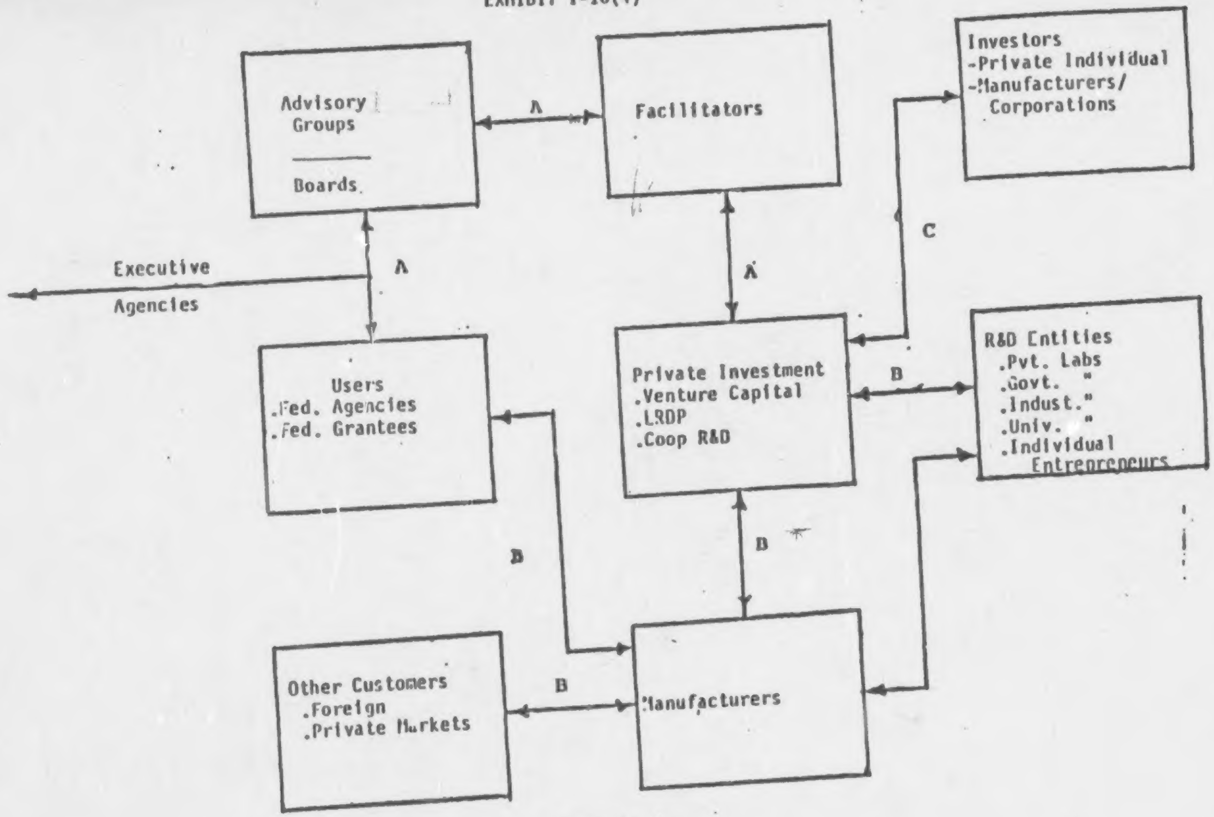
   identify suitable research areas

   screen and identify products

   provide advice in organizing research efforts

   provide useful technical information

EXHIBIT I-10(4)


Advisory Groups
Boards
A
Facilitators
Investors
-Private Individual
-Manufacturers/ Corporations
Executive Agencies
A
A
C
Users
.Fed. Agencies
.Fed. Grantees
Private Investment
.Venture Capital
.LRDP
.Coop R&D
B
R&D Entities
.Pvt. Labs
.Govt. "
.Indust."
.Univ. "
.Individual Entrepreneurs
B
B
Other Customers
.Foreign
.Private Markets
B
Manufacturers

R&D Process

Entities and Relationships

A - Advisory
B - Contractural/Licensing
C - Financial

EXHIBIT I-10(5)

4. Creation of incentives packages including

   assured markets

   anti-trust exemptions

   lump sum grants or "prizes" for successfully accomplished research

Initiation of such an activity by the government should begin through implementation of a pilot project. Such a pilot project would include.

1. identification of suitable research areas, and
2. identification of general partners through a competitive process.

The identified general partners would be provided with government assistance as outlined in steps 1 through 4 above.

Demonstration of successful assumption of a government research activity would provide a stimulus and a model for future assumption of such activities by the private sector.

EXHIBIT I-10(6)

Appendix

The Limited Research Partnership

In a limited research partnership, a general partner, acting as the manager of a research program, expends funds in the interest of obtaining some research result. The necesary funds are contributed by limited partners. The partnership, unlike a corporation, is not taxed. Gains and losses accrue directly to the partners.

The general partner usually contracts with a qualified organization to perform the research and may license this organization, or some other organization, to market the results of the research in exchange for a royalty.

The loss generated by the initial expenses on the research project, which will typically not be offset by gains for a number of years, are deductable as tax losses by the limited partners. Typically, a limited partner is able to deduct 85-95% of his initial investment. The funds available for performing the research are thus leveraged at a rate of 2 to 1 and the potential rate of return on investment is increased.

The general partner may be guided in his efforts by advisors who normally are not involved as partners. The advisors, which may be government or private laboratories, may share, in some way, in the benefits of the research.

If the research is successful, the payoff to the limited partners is generally better than the corresponding payoff with equity financing. A return may be received in the form of a royalty on the sales of the developed product. Such a return will be taxed at capital gains rate, further increasing the return on investment.

The above sketch outlines the primary factors underlying the concept of the limited research partnership. In practice, many complex issues are involved. More detailed basic information is available in the cited reference.

Comparison with Equity Financing

The use of limited research partnerships does not supplant the usual means of raising capital through equity financing, but supplements this means, and has both advantages and disadvantages compared with equity financing.

EXHIBIT I-10(7)

Advantages

As discussed above, profits from sales of a completed product of the research are passed through to the partners immediately and are taxed at capital gains rate.

With equity financing the only return on investment is from dividends which may not be declared until several years of profitable operation have been experienced, or from sale of stock. The dividends of course are taxed at ordinary income rate.

Losses due to expenditures for the research can be used immediately to offset other income of the partners.

With equity financing, the tax loss generated by research expenditures can be carried forward by the corporation but can only be used to offset gains from other sources. Such an offset may or may not result in a benefit to the investor in the form of dividends.

Disadavantages

Investors must have the resources to sustain the loss of their investments if the research is not successful. Although an interest in a partnership may be sold, the degree of liquidity is much less than with equity financing and the investor can not readily divest himself of his investment as he can with a corporate stock.

The possiblity of lowering or sharing the risk of research, or partially supporting it through current sales of developed items does not generally exist.

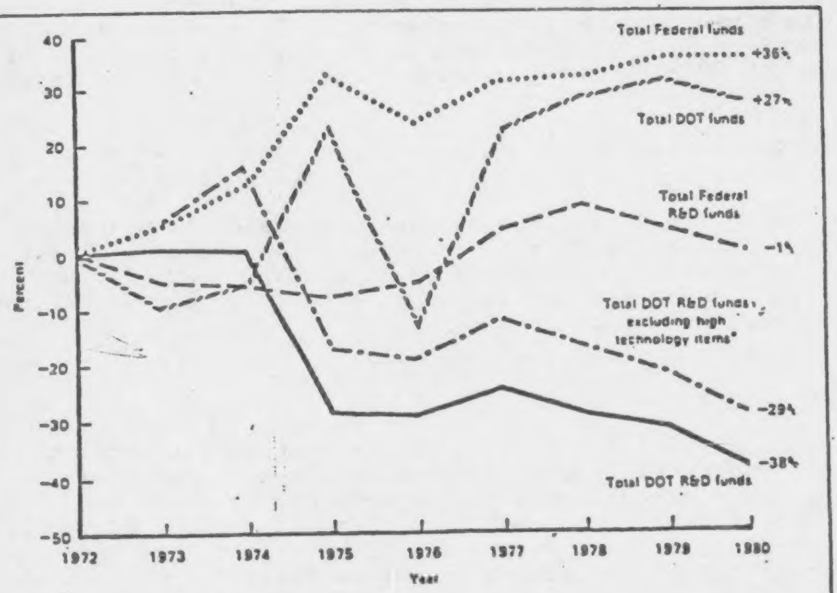
The investor must be willing to do without a return on his investment for a number of years until the research is successfully completed and a return from the completed research becomes available.

Reference: Nicholas G. Moore and Frank R. Pope: "The Fundamentals of Tax Sheltered Research and Development Financing," Coopers and Lybrand

EXHIBIT I-11(1)

National Science Foundation Study

Eight Year Funding Trends (1972 Dollars)



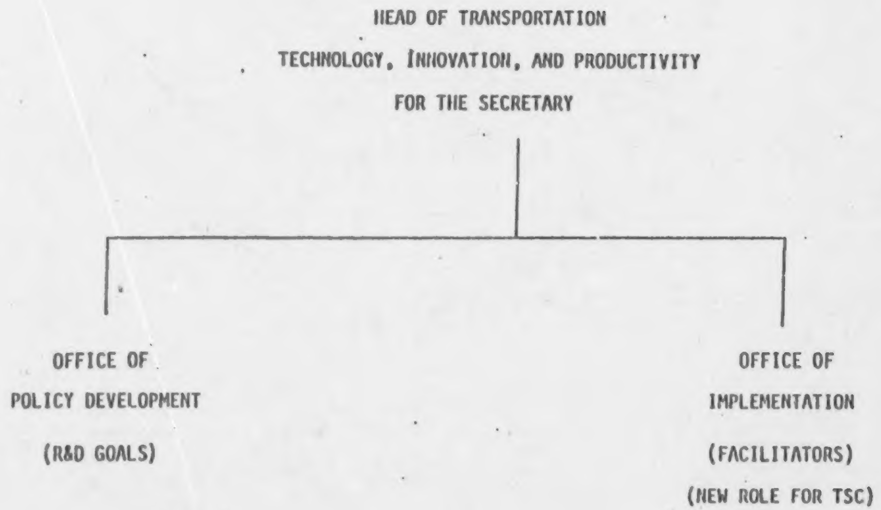
*High Technology items include the Urban Tracked Air Cushion Vehicle, Morgantown Personal Rapid Transit, Advanced Personal Rapid Transit, Linear Induction Motor, Magnetic Levitation, Tracked Air Cushion Vehicle, and Advanced Automated Transit Management System

Source. Federal funds for R&D, National Science Foundation (NSF)

Figure 1.—Eight-year funding trends (1972 dollars).

EXHIBIT I-12(1)

PROPOSED RESEARCH ORGANIZATION



HEAD OF TRANSPORTATION
TECHNOLOGY, INNOVATION, AND PRODUCTIVITY
FOR THE SECRETARY

OFFICE OF
POLICY DEVELOPMENT
(R&D GOALS)

OFFICE OF
IMPLEMENTATION
(FACILITATORS)
(NEW ROLE FOR TSC)

EXHIBIT I-13(1)

THE RESEARCH OUTLOOK AS A PLANNING ELEMENT

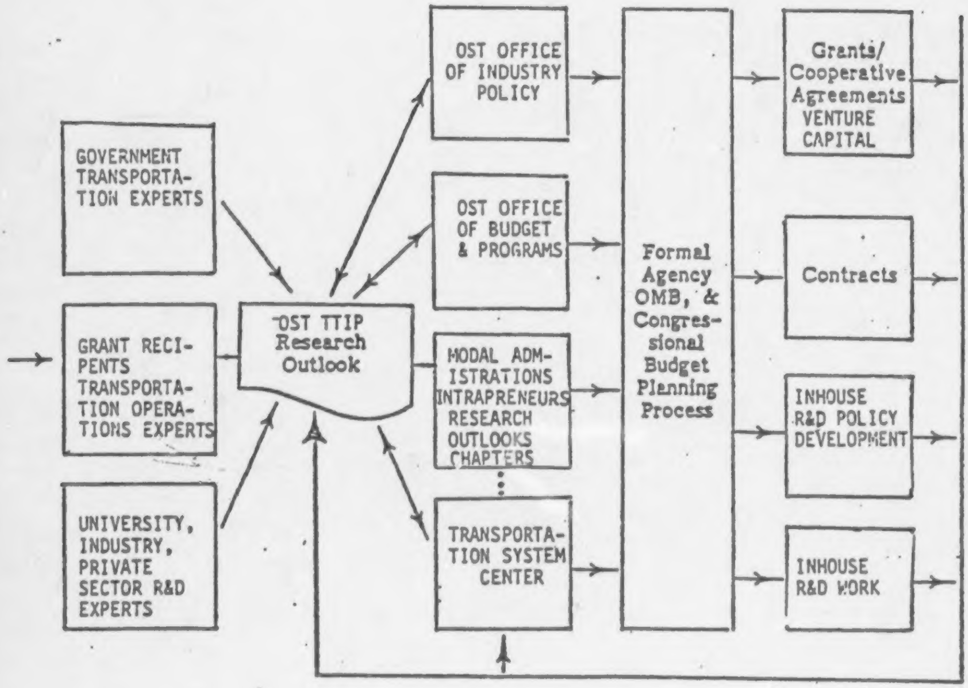

GOVERNMENT TRANSPORTATION EXPERTS
GRANT RECIPENTS TRANSPORTATION OPERATIONS EXPERTS
UNIVERSITY, INDUSTRY, PRIVATE SECTOR R&D EXPERTS
OST TTIP Research Outlook
OST OFFICE OF INDUSTRY POLICY
OST OFFICE OF BUDGET & PROGRAMS
MODAL ADMISTRATIONS INTRAPRENEURS RESEARCH OUTLOOKS CHAPTERS
TRANSPORTATION SYSTEM CENTER
Formal Agency OMB, & Congressional Budget Planning Process
Grants/ Cooperative Agreements VENTURE CAPITAL
Contracts
INHOUSE R&D POLICY DEVELOPMENT
INHOUSE R&D WORK

EXHIBIT I-14(1)

Recommendation No. ____________

COST SAVINGS/AVOIDANCE WORKSHEET

	COST ELEMENT	FIRST YEAR 1/	SECOND YEAR 1/	THIRD YEAR 1/	ADDITIONAL YEARS AS APPROPRIATE 1/	THREE YEAR TOTAL 1/
1.	DIRECT MATERIAL					
2.	MATERIAL OVERHEAD					
3.	DIRECT LABOR					
4.	FRINGE BENEFITS ON DIRECT LABOR					
5.	OPERATIONS OVERHEAD					
6.	OTHER DIRECT COSTS	73,000	-	-		73,000
7.	GENERAL AND ADMINISTRATIVE EXPENSE					
8.	TOTAL	73,000				73,000
	(DEDUCTIONS)					
9.	COST OF CAPITAL					
10.	ONE-TIME NEW-START COSTS					
11.	OTHER COSTS (Criteria Development Study for DOT R&D Programs)	500	-	-		500
12.	TOTAL	500	-0-	-0-		500
	SUMMARY:					
13.	ADJUSTED COST SAVINGS OF RECOMMENDATION (LINE 8 - LINE 12)	72,500				72,500

1/ In $000s

Mr. **Carney**. Thank you, Doctor. Now we will hear from Dr. Butcher, please.

Dr. **Butcher**. Thank you, Mr. Chairman.

Let me say first of all I am a civil engineer presently working at the National Science Foundation as a research administrator. I don't come from the highway field but from another section of civil engineering. I would like to address infrastructure questions in general but of course they apply to the highway transportation field just as they apply to other parts of civil engineering.

First of all, I must say I am pleased that research is the focus of these hearings because until now there has been little talk of research as part of our strategy for solving infrastructure problems.

Let my remind you that research is a multifaceted activity, basic and applied research as well as research dissemination, and demonstration. I come from the end of the spectrum that deals with basic research, and I believe that is the part which is perhaps most difficult to justify in connection with a question such as the one you dealing with.

Basic research is a risk investment with long-term payoff. Many of the public facilities we see today are products of basic research of a long time ago. They use the understanding developed by researchers many years ago. Basic research deals with creative ideas. Every year when we come to the Congress asking for funds for basic research we are faced with a difficult problem. What are we promising to deliver for the funds which Congress hopefully will give us? How do we measure the output? As the output won't occur for a number of years we really depend on the faith of Congress, expressing that of the community at large, that this has been a very productive process in the past, and that there is no reason to believe this process won't continue.

As research administrators, we try to exercise a quality measure on the product through the academic community which, in a sense, polices itself. Research proposals are sent to us, the National Science Foundation. These are not on any particular topic but rather from researchers who have some ideas they would like to work on.

We ask other researchers to see if they think the proposals embody productive ideas, that are worthy of public funding. If they are and the work proceeds, then the product of the research which is usually an article published in a professional journal. This is once again subjected to criticism by the authors' peers and it doesn't get published unless or until they approve, the product then is a paper product, continued funding of this by the Congress has been very productive. However, Congress action does involve a certain amount of faith that the research community can continue to produce.

The Department of Transportation presently has no research of this kind, and and has not reported basic research in its spending for a number of years. However, is not important as long as some organization in the community is harvesting the good ideas that bright, creative people can hopefully bring forward. Whether it is part of DOT's budget is not important. As long as there are places where researchers can get funds to work on their ideas.

The way research functions today is that most researchers are supported at a fairly low level as there is an overall shortage of funds. I will come back to this point later. Today there are problems as Mr. Deen mentioned, that are too big for a single researcher at a single university and somehow the resources to do this have to be assembled if we are to give these problems proper attention. I submit to you that the National Science Foundation, standing outside the mission agencies is perhaps the place that the Congress might see fit to say, "why don't you put a deal together that pulls on the private sector, the academic community, to work on these big problems. The Foundation is very flexible and indeed is able to handle specific research tasks."

I can give you an example of this from in my own division. We have a program we call earthquake hazard mitigation which is a very important problem impacting on the highways that are in the earthquake prone areas of the country.

In this connection we have been able to mobilize a lot of activity across the research spectrum which itself is unusual for the Foundation and in this we have used both academic and private sector researchers.

Let me move now to some topics in the infrastructure area that are easily overlooked and point to areas where research effort might profitably be directed.

First, the question of standards underpins all of our activity. To what standards shall our intrastructure perform? how safe? how pure? how wide? Answers to these determine indirectly the cost of what we do. In many cases standards have not been derived through rationale decisionmaking, sometimes for lack of data or knowledge. Research can illuminate these areas. This is a perennial problem.

Next are the problems related to new construction. In some areas, the research has been done to a great extent but there are other areas where research attention is not enough.

A third area where there is payoff for us tomorrow if we can get more attention to the research today is underpinning the repair and rehabilitation question, which is making new once again what is worn out. We don't know much about how strong a deteriorated structure is. We don't know how best to put it back. We need techniques to assess our deteriorated structures and to devise techniques to repair them. Repair and rehabilitation are two terms I use interchangeably, with rehabilitation referring to more extensive repairs. We need research to help us understand how to do that better so we can be more cost-effective.

Retrofit in my terms is making a facility do something it never did before. Starting with something old but producing a new thing out of it. As an example in the highway field, we have seen existing bridges having new lightweight decks added for higher performance than before. This is a good example of retrofit and there are many other examples in other fields. For example we can find old factory buildings functioning as shopping centers and the like. This is retrofitting. As we have so many deteriorated structures, it is more important now that we look at these and say can we use them as a starting point to bring them back to what they were or to make them something they never were before. No one has given this much research attention. New things are much more fun to analyze, while old things are not that exciting. I think it would be in our community's best interest to promote research on these topics.

The last on my list is operation. Operating smarter, I call it, looking to see if we can, with what we have make it work better than we thought in the first place? There is a good example from the water supply field. I'm sure Mr. Deen can supply something similar in the transportation area. Water supply affects all of us and in this region, Washington's water supply is supplied by several different authorities. It has been estimated that to keep up our water supply in the next 20 or 30 years would require large investments. Using research has been done over the past 10 years or so on risk assessment, synthetic hydrology which looks at and analyzes rainfall runoff, and modeling studies of the optimal operation of complex systems, it was found that by applying these techniques to the Washington water supply system that the separate systems can be put together into one big system which then can be operated to develop more water than the several individual systems. Due to this, investments on the order of $200 million or more have been avoided by this better, smarter operation. I submit that research can produce similar gains in the transportation area. For example, ramp metering which makes a highway carry more people than it was designed to do is an example of operating smarter.

Let me move now to the resources we the community are devoting to research. In this I have equated "civil engineering" with "infrastructure". Today, the Federal Government supports research in civil engineering, spending about $147 million. Of this, $23 million is spent at universities and colleges. The rest is in in-house activities of the Federal agencies. If we look at the non-Federal sources of funds, about $30 million is spent on highways, and that comes indirectly from the highway trust fund. I guess that about $20 million comes from other sources, with a total of $200 million for civil engineering or infrastructure research.

With respect to the number of researchers, it is hard to classify the research community. But at the National Science Foundation we believe it is too small. Researchers at universities have a dual function, teaching and research and the National Science Foundation is about to start off on a program aimed at bringing more people into the academic research community. We call this the Presidential young investigators program. In this we ask for cost sharing and through this we hope to augment the pool of teachers and students at the universities because there is a considerable shortage there.

I now want to compare the $200 million figure of total research expenditure with the volume of business that it relates to. It is hard to get the total annual infrastructure spending. Nonresidential construction which certainly includes it, represents an expenditure of $94 billion annually. The infrastructure-related part of this is said to be $25 billion. However, this relates to new construction which is just the capital investment part of the infrastructure. If civil engineering research is $200 million per year, that represents 0.2 percent of the annual nonresidential construction. If this is compared with the figures on industrial spending given in earlier testimony the infrastructure figures are low indeed. I submit these numbers are too small. I don't know what enough is but this is not enough.

At the Foundation today we are rejecting about as many good research ideas as we fund. Thus right away I could spend twice as much money as I presently get. If I had more we would have more people coming into the field. Money is the limiting factor in our research enterprise not good research proposals.

Research particularly at universities has in the past, produced lots of information and understanding, much of which has led to improvements in design, construction, and operation of our public facilities. I might also say many have not. Research is a risk investment and while there are some lemons, but there are enough research successes coming through that research is a good investment for the Nation.

As our community attempts to deal with the infrastructure problem as economically as possible, it is important that academic research be thought of as a part, small perhaps, but essential part of our total overall strategy. If our infrastructure activities are underpinned by a comprehensive, balanced, and well-funded research program, and we can be sure then that the practitioners who have to construct, reconstruct, and operate the infrastructure will be able to do the job of producing a proper standard of performance at minimum cost.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Butcher follows:]

PREPARED STATEMENT OF DR. WILLIAM S. BUTCHER, DIRECTOR, DIVISION OF CIVIL AND ENVIRONMENTAL ENGINEERING, NATIONAL SCIENCE FOUNDATION

Mr. Chairman and Members of the Subcommittees:

Introduction

Today, I only want to make one point. It is that as this nation moves to solve its infrastructure problem, whether it be the highway and transportation aspect of it or the other parts, that the research community, particularly that part of it that exists at our academic institutions, should be regarded as an essential piece of any national strategy.

In this connection, I want to point to some of the questions that the research community might well give its attention to and then discuss briefly the resources that are needed for that community to play its role and the extent to which these resources are available.

The Infrastructure Problem

It is clear from the many public statements and our own private observation that the community's infrastructure is, to a greater or lesser extent, in need of considerable improvement. Published estimates of the cost of doing the necessary work have been reported as high as $3 trillion. Other estimates, such as the recent Congressional Budget Office statement on "Public Works Infrastructure: Policy Considerations for the 1980's," which deals with the Federal responsibility in this area, indicates a much lesser total needed expenditure. While the needed expenditure can be debated, it is clear that the solution to the problem is going to involve expenditures greater than we are presently devoting to that area. I believe that the research community can make an important contribution to ensuring that what must be done is achieved better and more cheaply than might otherwise be the case if its essential role is not recognized.

Four Kinds of Research Activitites

The research enterprise has four separable activities. First is "basic" research, which deals with fundamental or generic questions, and allows us to understand broad classes of problems. Today's engineering practice draws very heavily on basic research done in the immediate past, and more particularly, in the not-so-immediate past. The payoff for basic research is often deferred. One research project might be thought of as one piece of the puzzle and when all the pieces are in place, the whole picture emerges and we can see more clearly how to go about our business.

Basic Research:

Basic research is essentially a creative process and the National Science Foundation aims at fostering that creativity through looking for good ideas, sifting these as best it can, and then giving sufficient funds to those who appear to have the best ideas to enable them to carry these ideas forward. The end point of the activities in this area is usually articles in professional journals which are then read by other researchers who may want to carry the work forward or other professionals who may use the ideas so generated in either their applied research or in practice. As basic research is a creative process, it is best carried out by those who have freedom from day-to-day concerns to give their attention to exploring the frontiers of knowledge. The people in this community who have that kind of situation are the university researchers. They are continually stimulated by the young bright minds that are clustered around them as graduate students and as research assistants. While the total amount of money spent on basic research at our universities that bears on the infrastructure problem is fairly small, being in the vicinity of $20-30 million depending on one's definition, it is vital that we protect this money and amplify it, if possible, to keep up the supply of ideas that will enable us to solve our infrastructure problems better. In view of the magnitude of the problem, even small advances can be very cost-effective as far as the community as a whole is concerned.

Next, a word about the nature of academic research. Much academic research is basic research involving thinking, trying out ideas, and trying to understand phenomena, usually through fairly small-scale tests of, for example a model, a soil sample, a test structure, a full-scale test of a structural element, or a computer model of a transportation system, water resources system, and the like. Activities such as these are commonly carried out by one researcher with some graduate students who learn from their professor in this context while carrying out the research under his guidance. In recent times this pattern of research has tended to dominate our basic research and has been criticized because it reflects the fact that funds for research are small and that in an attempt to spread available funds as widely as possible, they are spread a little bit too thinly so that big ticket items tend to be put aside.

Applied Research:

Second is "applied" research, which deals with applying known information to specific problems and finding out how to solve them best. This research deals with more immediate problems, uses specific information that is related to a given site, and may also use basic information which has been with us for a long time.

Research Dissemination:

Research dissemination perhaps is the orphan of the research activities. Research disseminatinon happens in our community through a number of traditional means and those of us who were trained in the past have been subjected to these. For example, our teachers had knowledge which they transmitted to us through formal classes and through research which we undertook with their guidance. Also we go to professional meetings and hear about new research ideas. Research dissemination seeks to speed up this process. It is like putting a pump in a pipeline to speed up the flow. Its mission is to get new information, both basic and applied, out to the profession rapidly so it can be used immediately rather than wait for the traditional processes that work slowly. In a rapidly changing era, research dissemination is necessary. Otherwise research will not reach those who need it until later than would otherwise be the case, resulting in losses due to the lack of use of better information.

Demonstration:

The final step in the research process is demonstration. Until there is demonstration that new concepts, new procedures, new structures can in fact be built and will perform satisfactorily, there is reluctance on the part of those who must pay the cost to provide the necessary funds. Demonstration is expensive and should be used sparingly but it would appear not to have been as much a part of the scene in recent times as it was in the past.

Within government, research is handled in different ways. The mission agencies, being concerned to do their mission as best they can, focus on applied research with possibly some research dissemination and demonstration. For example, in the highway and transportation field there are many researchers both at the Federal and state levels. Basic research, with its often long-term payoff and high risk, is commonly a small part, if any part at all, of the research activity, even of a Federal agency. The exception to this is the National Science Foundation whose principal mission is to support basic research in all aspects of science and engineering. The National Science Foundation spends virtually all of its funds on basic research at universities with a few notable exceptions.

Infrastructure Research

Let me now turn attention to a number of the problems that would appear to be appropriate for further attention in the context of the needs of the infrastructure.

Standards:

First, there is the question of standards. The standard to which a civil engineering structure or facility should perform will, in large part, determine its cost. In the past, many standards have been set without due regard to this cost involved and this can result in the misallocation of resources by building some facilities too strong, too safe, or to wide when the extra funds might better have been used on other facilities that are thereby crowded out. Only through research can we understand the implications of standards in terms of performance and at the same time they can be costed out so that proper economic decisions can be made in setting standards. It is also true that we can partly meet the cost of our infrastructure by adjusting our standards where they are higher than now deemed necessary. The question of standards is directly related to the question of performance. Through research we can further illuminate the tradeoff between performance and cost, leading to better decision-making in today's context.

Research Related to New Facilities:

A second area of research which has been the focus of most of our attention in the past is that which relates to new construction and facilities. There is no reason to believe that the progress that has taken place will not continue, and therefore continued investment in this kind of research remains important.

Research on Problems of Repair and Rehabilitation:

However, the present state of the infrastructure problem is bringing into greater prominence the question of repairing it to return its performance to what it was. Research related to topics involved in repair, rehabilitation, and maintenance has not been perceived as an important area in the past, although it hasn't been without some attention. I believe research might well be directed to topics related to problems such as assessing the strength of a deteriorated bridge, through doing research on how we can come up with a specific value of strength of such a bridge with research on the problems related to optimal remedial measures to recover the strength.

Research on Topics Related to Retrofitting:

Another realm for research, which is related somewhat to the above, is to take parts of our infrastructure either in good condition or in deteriorating condition, and so modify them using modern materials, modern methods, or modern understanding so that they perform even better than they were intended. An example of this in the past is taking a bridge and adding a light-weight but wider deck so that it carries more traffic. There are examples in other realms of the infrastructure and the experts in these various areas can indicate what would appear to be the opportunities. As an example outside the highway transportation field, we might look at some older buildings in our inner cities which are being refurbished as apartments and shopping centers, uses which were not intended. By using an obsolescent structure, it has been possible to convert them, with some cost, to a function which was never intended by their designers but thereby producing an important community resource.

Research on Questions of Operation:

The final aspect of the infrastructure problem that might benefit from research is the operation of our systems. An example I am fond of recounting is related to the Washington water supply system. As part of an accounting of needed infrastructure spending, it was estimated that something on the order of $400 million would be needed before the end of the century to make sure that Washington had an adequate water supply system. It has been found, using modern methods of computer simulation, synthetic hydrology studies, optimum operations studies, and studies in risk assessment--all the products of research over the last twenty years--that when these are brought to bear on this problem, it is possible to spend a small amount of money to link the individual systems in the Washington area and then to so operate them together that Washington will have an amplified water supply system at little or no additional cost. One might characterize this as operating smarter. In the highway field we might note that ramp metering, which can be installed on highways at small cost, offers the opportunity of increased capacity with no increase in overall construction. If research can be carried out on basic topics, followed by applied research, dissemination, and demonstration to show that new ideas can work, then they can be adopted broadly leading to savings in what might otherwise be the cost of meeting our infrastructure needs.

Research Resources

The resources to carry out research are of two kinds. First there is the dollars. From the published statistics it appears that the Federal government spends approximately $160 million per year on research in civil engineering. This is both basic and applied and is spent on all performers, both at the universities and colleges as well as within the Federal government's own establishment. To this might be added about $30 million from state funds that is spent on highway research. Private companies also spend a small amount of money. Thus, the total expenditure from all sources would be close to $200 million per year. Estimates have been given determined from the funds that are being spent on infrastructure related activities. This is about $100 billion per year. Thus, about .2% of the total infrastructure spending occurs as research. My assertion is that this is too small. Any industrial organization that spent only .2% of its revenue on research would see this as seriously underfunded. I estimate that not more than one-sixth of this amount of money is spent on basic research. This is an area that is underfunded now and will become more so as increased attention is directed to infrastructure problems.

I know from personal experience in the National Science Foundation that the funds needed to support good research ideas in civil engineering, which are now not funded for lack of funds, is about equal to the amount of money that is actually spent. Clearly we could spend twice as much money on basic research as we do now and spend this productively. If additional funds were available, then even more claimants would come forth with good ideas. It should be noted that the Reagan administration is sensitive to these concerns and in fact has proposed for FY 1984 that the civil engineering research spending in the National Science Foundation will increase by 15 percent. This is a step in the right direction but I believe that even further spending beyond this would be in the best interests of the Nation.

A limiting factor on academic research is the extent to which the academic researchers needed to carry on these activities are out there. It has been estimated that the Nation's engineering schools are short of between five and six thousand faculty members. However, in spite of the faculty shortage, the engineering schools are doing a good job of training. Increase in enrollment has taken place in recent times. But there is cause for worry in this area and maybe in others, that the demographics are pointing to problems in the near future. By this is meant that the age structure is such that faculty presently on board will be retiring in the not-too-distant future and that the lack of hiring in the recent past and present times means that we have no cohort of leaders coming up to fill the ranks of the people who will all retire more or less simultaneously. The National Science Foundation is attempting to alleviate this problem by initiating the Presidential Young Investigators Awards to attract young men and women into the ranks of academia. At the same time, the Directorate for Engineering at the National Science Foundation has had a Research Initiation Grants program for almost twenty years. This latter program provides an entry mechanism into the research fraternity and has been very successful.

Summary

Research, particularly at universities, has in the past produced lots of ideas, many of which have led to improvements in design, construction, and operation of our facilities. As our community attempts to deal with the infrastructure problem as economically as possible, it is important that academic research be thought of as a part, small perhaps, but an essential part of our total overall strategy. If our infrastructure activities are underpinned by a comprehensive, balanced, and well-funded research program, we can then be sure that the practitioners who have to actually construct, reconstruct, and operate the infrastructure will be able to do the job of producing a proper standard of performance at minimum total cost.

Mr. **Carney**. Thank you very much, Doctor.

I would like the three panelists if they would to stay here for a moment while some of the members ask questions of them.

I would ask my colleague from Rhode Island, Mrs. Schneider, if she has any questions of the panelists?

Mrs. **Schneider**. I will begin with a statement that will replace the statement I didn't make at the opening.

I will say that listening to the very expert testimony you have provided us with has been most enlightening. At the same time I cannot help but think that more money is not necessarily going to be the answer. I have sat on this Science and Technology Committee for 2½ years and I have in this very, very short time watched technologies come and go in a broad area, pollution control, energy development or whatever.

I am very much of the opinion that there must be from what you gentlemen are saying, I have to try to read between the lines, there must be some planned obsolescence in the construction of roads. It seems that there is intention for perpetuity of road building and whether it is the white collar workers, the engineers, civil engineers or whether it is the blue collar workers who are part of the construction firms doing this, I don't know. But we always talk about a lightbulb that will last for 2 years or for those ladies in the audience, stockings that will never have runs in them.

I think we know we have the technology to develop those things but they are just not forthcoming.

Are any of you gentlemen familiar with the work that has been going on at the Franklin Institute in development of what is called echo rock?

No?

Well, good, maybe I can share some information with you.

I have learned that there is a material, a blacktop material that has been developed at the Franklin Institute that is the byproduct of sewage sludge which is being recycled. This material has been used on roads for the past 6 years now and no potholes or cracks or other aberrations to my understanding have occurred.

I have not seen the site myself but this is the testimony that we have had the benefit of before my committee.

It seems to me that we have an enormous problem with the disposal of our sewage sludge in this country. We have an enormous problem with not being able to fill all of our potholes, when we talk about the repair and rehabilitation. And why the connection isn't made there, I don't know. Perhaps you gentleman could further investigate this particular product to see if it does indeed have value for what we are looking for.

Another question, Are any of you familiar with the way they construct roads in China?

No. Well, OK, I just had the good fortune to visit China and it was very interesting to note that as I traveled for many miles along a side road right beside where they were building a major highway, of course it was far more labor-intensive than what this country has seen but the roadbed was about 6-feet deep and you can see the striations of different types of rock being used, each time being leveled and pressed down.

I am not using the right words but at any rate you get the picture.

And we questioned some of the Chinese people with us and their estimate is that this highway will last for hundreds of years and watching the care with which it was done and watching what perhaps may be a very primitive approach by our standards I cannot help but think by looking at the China Wall that their highways will also be around as long as the China Wall has been around.

Perhaps we are asking to sink more and more money into high technology when in fact the solution may be more simple. I don't know. I will be very interested in hearing comments on anything that I have said so far this morning. Feel free to, any of you, speak up.

Mr. DEEN. I would like to comment if I could, Mr. Chairman.

Mr. GORE [presiding]. Please.

Mr. DEEN. I think first of all you have to realize that the Interstate Highway System was designed for a 20-year design life as specified in the congressional acts that established its construction. We know how to build roads that last longer than that but they would cost a lot more. So the issue is not whether we can build a road that will last 40 or 50 years, it is a question of can we do it at a rate that people are prepared to pay.

We can do anything with enough money. This call for research is to learn how to do these things more cheaply. Better materials would allow us to build a thinner pavement to carry a heavier load for a longer period. We can build a thicker pavement to do that now but it costs more. It is not a question of being able to do it, the question is the economics.

It is important for us to keep that in focus.

In reference to the material that you came upon, I think it is important to note that there are a number of materials like this that are brought to the attention of highway management each year. I hear about them all the time and one of the problems that we have is that our ability to test these materials is limited by our research budgets. States often undertake a test, and sometimes a test will take many years, but State administrations change, and often times these are not followed through. Also, the information is not shared.

There are materials out there that many claims are made for and our ability and our level of research effort is sufficiently low that often times we cannot test and verify these thoroughly.

Dr. BUTCHER. Could I say something about the echo rock you mentioned. I don't know it by that name. Some years ago the National Science Foundation under an old applied research program, no longer present, did have the result of the development of a brick composed partly of sewage sludge.

I believe it is being produced by a firm in the Maryland suburbs. Highway repair and sludge are two bulk problems for the metropolitan area, so we might put two problems together and get a solution. Unfortunately, the amount of sludge you can use in the brick is not equal to the task, not equal to the task of disposing of it, but it is moving in the right direction. I understand it is being produced here today.

Mrs. SCHNEIDER. Thank you.

Dr. **Belle Isle**. I would like to respond as well, Congresswoman. My sense of the problem is not throwing more money at it either. I don't think the solution is to throw money at it. I think the solution is in the structures by which we do research and the strategy by which we do research.

For example, MIT has a materials science laboratory and in that lab they do research on various alternative materials. One of the materials is ceramics as potential application for highway construction. In that lab they have over the years moved away from Government funding for research because that funding has never been consistent to allow critical mass research over a long period to really look at those materials.

They are using private sector money to the tune of 90 percent of their total funding to look at some of these ideas.

I believe that the real problem is the structures by which we do research and not the dollars that we throw at research projects. I think we fragment research dollars and do not think strategically about key materials or technologies that are essential to solve some of these problems. We keep whiplashing back and forth and fragmenting our dollars around multiple goals and spending programs and never achieve the kind of advancements that I think you are referring to.

Mrs. **Schneider**. Well, both you and Mr. Deen have stated that the research system is enormously fragmented and there needs to be a focus. I would hope that perhaps this committee could take some action in giving directions toward the appropriate body or bodies and insisting that we have some focus.

I, for one, am not at all inclined to vote for any budget that includes any money at all unless we know what we are going to get out of it, and we have a specific job description. It is overwhelming at times to see how many problems we are faced with on a daily basis in this body, and it seems to me like such a simple problem compared to many of the others like medicare and other things we have to grapple with that I would certainly hope that this committee could take some directives based on your testimony and get some answers.

Thank you.

Mr. **Gore**. Mr. Carney.

Mr. **Carney**. Thank you very much, Mr. Chairman.

I think one of the areas we might be overlooking is the repair and rehabilitation of the existing infrastructure and the longer we do that, the more it will cost to get them up to par.

I have a couple questions there. One is, are there any new innovative technologies that are right around the corner that might be available in the short term to help in the resurfacing of existing roads, to help in the rehabilitation of bridges, et cetera? That is a question open to everyone.

Dr. **Belle Isle**. To respond to that, I believe the one material I mentioned, sir, is ceramics. That is a material being used—looked at for both repair and for basic production of the infrastructure, itself.

It is a material that has a lot of other applications as well. It is being looked at for more than just highways. For example, in high technology chip research for housing of semiconductor chips, it is another highly valuable material. So I think in some areas there is a possible synergy that we don't just narrowly say what is an answer to this particular problem?

I think if we could say that we have the possibility of synergies to focus on various materials research that have multiple applications, we will get the benefit of including more brainpower and more research and more focus on various applications of a single material. So I don't think we need to go down the road of identifying new materials. I think the issue is to take some of the materials we know currently exist and begin to work on various applications with those materials.

Mr. CARNEY. Are there any problems associated with the technology transfer into the applied area caused by either industry, labor or intergovernmental relations? Are there things available now but for one reason or another—not economics, but for other reasons—that we cannot use? For example are there materials that would be less labor intensive and would get resistance from organized labor or materials that would perhaps have an enormous economic impact from the sense of dislocating all asphalt manufacturing companies, or problems associated with the intragovernmental relations such as the Federal highway moneys going to the States and then on to local authorities?

Would this stop us from introducing new and innovative technologies and techniques that would allow us to repair, replace, or construct new types of roadways and bridges?

Dr. BELLE ISLE. I would like to respond, if I may. I think the answer to your question is you can find examples of all the things you have mentioned. The point I am trying to make with the study we did in the Department of Transportation, this fragmentation and lack of integrated systems where you can bring the various parties together and identify ways to achieve goals that does not appear to produce adversarial relationships is essential, but there is lack of communication and structures and mechanisms to bring these people together to communicate around essential strategic goals, like materials for highway repair and construction, to say how we do that together as opposed to fighting one another in the process.

I think the issue is how we get national collaboration on key goals and get beyond the adversarial relationships that sometimes exist between the factions you mentioned.

Mr. CARNEY. Mr. Deen.

Mr. DEEN. I think there are examples of that. We operate our highway system in a very decentralized fashion. That is the way we operate our country. That has strengths, it also has problems that you all face daily, I am sure. The strengths of the way we operate it are obvious, and I think it is important and I am not advocating we centralize research. I think decentralized research has been effective over the years and I think it can continue to be. It has shortcomings I have pointed out in terms of focus.

If there was one single thing that I would point out as far as institutional problems in research it is the turnover of management in this industry. Both at the Federal and the State levels, there is an enormous level of turnover at the top of these major large public-sector entities that construct, maintain, and operate the Nation's highway system.

I don't know that anything can be done about that; it is simply an observation. But it is difficult when you are talking about managing something that is intrinsically long range to manage effectively when you have a large turnover. AASHTO says there are 20 new State chief administrative officers, as they call them, (the heads of State departments of transportation) in the last 18 months. It is difficult to manage long-term activities with that turnover. The same thing happens at the Federal level, by the way.

Mr. CARNEY. One last question, but first I would like to thank personally all three members of this panel. It has been very, very enlightening. We had an opportunity to read your testimony, it is very complete and I am sure we will get many things out of it.

Aside from those problems associated with the application of new findings there seems to be to me a major stumbling block in this. When you consider the fact that the Wilson Bridge, which probably everybody in this room travels at one time or another, will cost us $60 million to repair, hopefully less because the contractor is ahead of schedule and below cost, but that is the precise amount we are spending in research and development for all the highways in our entire Nation, if I understand correctly.

Mr. GORE. That is correct.

Mr. CARNEY. Now that is a span of less than a mile. If we can come up with a material that will make that thing last for 40 years, it would be miraculous.

Mr. GORE. That is right.

Mr. CARNEY. But there has to be something hidden out there that just—it just seems to be too damn simple. We should be able to do a better job. I hate to bicker on that Wilson Bridge, but we fix a pothole, and it is back the next day. On any highway we just keep running into that. I can't believe with all our resources—I am inclined to agree with my colleague from Rhode Island, that it seems like everyone knows the problems and I can't believe the solutions are that difficult.

We can find materials that can withstand enormous amounts of heat to bring people back out of orbit. We can put a shuttle into orbit. We can fly it across the Atlantic just to show it to folks in Europe, and we can't fix the potholes on the Wilson Bridge. It boggles my mind.

I don't mean to throw it at you, to say you are not doing your job. But why is that?

Mr. DEEN. I think your comments are enlightening. If you look at the money spent to get the heat resistant reentry material for the space shuttle, it is probably more than we have spent in all of highway research in many, many years. It is certainly far more than the materials research that go into roadbuilding for probably since we started building roads. So I think there is a vast difference in our spending, and I think that probably it stems from the fact that, as two members of the committee have said, road materials are so simple, why should we spend on it. But it is not that simple. If it was, we would have solved it long ago. We simply don't launch the effort necessary to make real progress.

One last point before I lose this, I was talking to the director of research for IBM about some of these problems in the last couple months, and he looked at the nature of the problems that were involved. He presides over a $250 million research budget for that one company, and they are a $30 billion company, while we spend $40 billion for roads in the United States I described some of the big research problems that I thought we should be attacking, and his response was, "Well, I wouldn't attack any one of those problems if I amassed all the research money you are spending on all the vast subjects you study."

We simply don't get the critical mass of resources focussed on a single problem. This is the same as what Dr. Belle Isle is saying, we don't have a critical mass to attack some of these larger materials problems.

Mr. CARNEY. Just to follow up, and I will yield back to the Chair, do any of the panel members feel there is an underlying belief in the transportation industry that we should be moving away from this type of transportation and moving into more exotic types of transportation, people movers, high-speed railroads, this type of thing. There seems to be a movement to get people out of their automobiles and get people off the highways.

I don't see that ever happening. You can put the Metro from my front door to my desk, and I am driving my car. [Laughter.]

But is there a movement there where we, the Government, might be saying "Let's put more money into other areas of transportation, let's let them be the stepchild because we want to move into new ideas," and therefore you are not getting your fair share?

Mr. DEEN. I believe 20 years ago we saw a lot of studies and a lot of people who believed that we could, by inventing or developing new technology, get people out of their cars and who knows, the future may yet see that. But the studies I have seen more recently in the last 3 or 4 years, addressing what the system of 1999 or 2000 and beyond will look like, I think the consensus of those studies is that at least for the next 20 or 25 years the system will look much as we see it now. Beyond that, who can tell?

But we need highway research now for problems that are within the next 20- or 25-year scope.

Mr. CARNEY. Thank you, Mr. Chairman.

Mr. GORE. Thank you.

Let me say, before recognizing the next member of the subcommittee, that investigative hearings like these are designed principally to identify obstacles to the public interest and identify ways to remove those obstacles. If we are indeed on the verge of a massive new round of spending on our infrastructure and if in fact we could maximize that investment and save billions of dollars over the next several decades by paying more attention to transportation infrastructure research, then we need to figure out how to get that done.

That is what this series of hearings is all about. I think the three statements—and I looked at some of them last night, and I am doing some more here, and I want to apologize for not hearing your oral presentations but I had to be elsewhere.

Mr. McCandless.

Mr. MCCANDLESS. Thank you, Mr. Chairman.

I would like to apologize, the County Supervisor Association is down the hall on the very subject we are talking about, how are you going to help us take care of our roads. That is my delay in coming.

I come from the southern California area where I am directly involved in the movement of something like 7.5 million cars a day from one point to another, not Mr. Carney's car, but others. I have had experience as a county supervisor in trying to maintain a road system, but for purposes of zeroing in on what you have said, let's take the Interstate System as we understand it and has been applied today as a benchmark.

If I understood your comments, Mr. Deen, you said the 20-year design was built into the system and that materials, engineering, and other components are there to make it a 40-year or 50-year or 100-year, whatever it might be, system but that cost was the factor in setting up the 20-year design, that you could get more miles for a certain number of dollars, obviously.

Interestingly enough in my coming back to Washington, I took the Interstate System from California, and I noticed the differences in the level of maintenance and level of construction and what appeared to be level of design in its original form. If we can use the technology to be able to make a roadway in the way you are talking about, and the Roman's did that, we can still see their roads; of course, then isn't money the factor?

If we have the technology, if we use a certain amount of decomposed granite, certain amount of base, certain amount of oil in the mixture or whatever the components may be, then what is left to research if we decide we are going to have a quality product, and then the design and engineering and application of that in the construction represents the technology that went into the specifications and the design?

Why are we having problems then if we have the technology other than the fact we pick a point where we say the cost-to-benefit ratio after 20 years is not what we are looking for?

I will offer that question to any of you.

Mr. DEEN. I think if we had had a concrete with 50 percent greater strength in it, and we had that 25 years ago, we might not be looking at the deterioration of the interstate that we have now at the joints and in the bridge decks. If that concrete had had qualities that didn't allow the salt to penetrate in and corrode the steel, we would not be looking at those problems. We would not have had to spend more money. That is the difference.

If they had originally authorized $60 billion instead of $40 billion for the interstate, we could have put a 40-year life on it. But with only $40 billion, if we had known more 20 years ago, we could have built it and not had these problems. That is an oversimplification, but it is a response to your question.

Mr. MCCANDLESS. Let's build on that because that is a flaw in your statement that we don't have the technology to be able to build a 40-year highway.

Mr. DEEN. Oh, no, we could have built it with more money by making the pavement thicker and putting in more steel.

Mr. McCandless. I misunderstood you. I thought you said if we had concrete of a quality that would resist the salt, we could have used it.

Mr. Deen. We are mixing a couple things in there. Say we could have built a 10-inch pavement that would last 20 years under certain loads and so on for a certain price. We could have built it 20 inches and it would have lasted longer, but it would have cost much more.

If the concrete had been twice as strong, we could have built it 10 inches thick for the same money, and it would have lasted longer. We can do it with money, or we can be smarter, and the plea for research is to be a bit smarter so you don't have to spend so much money in order to achieve the same result.

Mr. McCandless. Take the concrete and use that as a point of demarcation. Portland Cement, others who provide a nationwide product of this nature, I have some experience with the Portland people in the Colton operation. They have an R&D laboratory as a means of keeping up with the competition.

We are saying here then that that laboratory and what it produces needs to be augmented by some factor, whatever it may be, in order to produce this 10-inch concrete and we would like to have it, but we would have to use 20-inch with our current knowledge in order to get the same result?

Mr. Deen. Well, there are several things about that. The Portland Cement Association, which I think is what you are referring to, does have a fairly extensive laboratory and research program.

Mr. Gore. May I interrupt and say that they are going to testify next week at another in this series of hearings.

Mr. Deen. Representatives of that group tell me the amount of R&D they are doing in product improvement has substantially declined over the past 20 years and it is still declining; that there is no incentive for management to spend money in product improvement because for a variety of reasons, one of them being that our method of procurement, we specify the product required and the opportunity for selling an improved product with long-term durability is one that has very limited potential for payoff. They don't see the incentive for doing that.

Dr. Belle Isle may want to comment on this, but I have met the director of research for his company, Martin Marietta; they are a company with a lot of areas in research, and I asked what research was done in the cement area because they happen to produce a lot of Portland Cement, and he said "We don't do any research in Portland Cement."

I said "Why not?" He says "There is no incentive to do it because it is a situation in which the competition comes by providing it at the lowest possible price; it is a bid against specifications for the lowest price, and the low bidder gets it and delivery as agreed to provide the service."

So there is not the incentive for the private sector in some industries to do that reasearch.

Mr. McCandless. That is a part of the design requirement; in other words, the Department of Transportation, or whoever puts out the design specifications for a given length of interstate highway, saying it shall provide a certain this and that and so on, and they are holding the trump card when it comes to the quality and life expectancy of the materials.

Mr. DEEN. They are not doing——

Mr. MCCANDLESS. All they are doing is saying they want another five-sack mix or whatever the terminology is, so everybody provides the five-sack mix rather than say "If you can provide us with a material that will withstand salt for a period of time," and et cetera, et cetera, "that that will be a consideration in the ultimate award of the contract," or whatever.

It would appear to me that those would be incentives for research.

Mr. DEEN. Incentives could be altered and that is something too that needs to be looked at. In the situation you just described, the State DOT who put out the specifications, would have to have the research capability required to examine that product. Simply accepting the claim of the bidder that he can produce this stuff that is twice as strong is not adequate. You get those claims all the time; you have to have a research program to evaluate those claims. We are not in a position to do that effectively now in some cases. Certainly not enough to evaluate this product improvement you describe.

Mr. MCCANDLESS. I hate to bore the panel with a lot of personal experiences, but going back to concrete, we built a 1,200 square foot house from the ground up in 4 hours and 28 minutes, and that slab was cured and they were putting nails into it within less than an hour. That would appear to me to have certain technology and know-how as to how to handle the commodity of cement to produce a certain result.

I have a lot of problems with some of the dialog here. Please, I am not an adversary to what it is you are saying. I guess I have just enough information to be dangerous here over the years, and I have trouble putting it all together.

Mr. DEEN. I am not saying that there are no advances. As a matter of fact, I am told by concrete experts that all the technical papers now in the professional societies for improvements in concrete are coming from outside the United States, they are spending more, particularly in Europe, and they are advancing, for example polymers in concrete or use of gels in concrete that provide certain properties that make it stronger than the present concrete. Those developments are coming from outside this country primarily.

I am not an expert in the concrete area, but that is what I am told.

Mr. MCCANDLESS. Are we in need of research in other commodities in this interstate scenario beyond that of concrete?

Mr. DEEN. Yes, I mentioned——

Mr. MCCANDLESS. Is that the weak link?

Mr. DEEN. No, I wouldn't single out that. I think all the basic materials, asphalt I singled out, and I would urge you to look at that. We think asphalt, perhaps given the fact we are moving into a more maintenance and rehab phase rather than new construction, that indeed asphalt and materials, methods, processing and training, that whole smear of activities is an area that is at least in as need as much as Portland Cement.

Materials are not singled out either. There are a couple others we mentioned.

Mr. McCandless. The Asphalt Association of California or the United States, or whatever their trade organization is called, they are not doing any research? They are not able to offer what it is we want in the way of a quality product?

Mr. Deen. There is an asphalt association that has been in business for many years. I guess it is the counterpart of the Portland Cement Association. At a time when there was a lot of competition between concrete and asphalt people for construction of interstate; there was a fair effort made for product improvement and in service to the people out there using it.

Those institutions in both cases have declined their activities substantially as competition has declined, and indeed as the whole upheaval in the economics of the oil industry where we get the asphalt has influenced this.

Asphalt is a big thing to the highway industry; 18 to 20 percent of all the money we spend is spent for asphalt in place. It is only 4 percent of the revenues of the oil industry, though. It is low priority. If any of us were management in that industry, we would not give it much priority. They are probably producing asphalt as a service to government, but it is not going to be something that will inspire them to spend a lot of extra money in product improvement.

Mr. Gore. Will my colleague yield?

Mr. McCandless. Yes.

Mr. Gore. We are also going to hear in one of our hearings next week from the Asphalt Institute and the National Asphalt Pavement Association; both of them, and in reference to your earlier comments about the English research, we have the vice chancellor of the University of Surrey from England, Anthony Kiley, who is one of the leading cement researchers in the world who will testify. So we will revisit some of these subjects in depth.

Mr. McCandless. I would only comment that my experience with asphalt is that the oil companies only supply the basic ingredient in tank carloads and that the batch plants, with whatever it is they use in the way of commodities, are aware that the key—at least in the West—so it would mean the batch plant would be looking for ingredients beyond that of simply the oil product in their raw materials that they use.

Mr. Deen. I think you have hit on another aspect of this. There is no single item you can point to and say that is where the research ought to be done. You have the source of the basic crude stocks, you have the refining process, you have the batch plants and the aggregates and additives and asphalt materials mixed in, you have the people in the departments of transportation specifying the mix designs, and you have the people in the construction process, and you got the researchers. When you get a group of these people in the room to see what is causing problems in asphalt, there is a tendency for all fingers to be pointing in different directions. There is no single place where any substantial effort is being made to look at all these elements as a system where they are working on a sustained basis. It is a fragmented process.

Mr. McCandless. Thank you, Mr. Chairman.

Mr. **Gore**. Mr. Durbin.

Mr. **Durbin**. Thank you, Mr. Chairman.

I am sorry to have been late and even with the best transportation system in the Capitol, we can't accomplish that.

I am only going to ask you one question, Mr. Deen, and I invite the rest of the panel to comment. You seem to suggest in your earlier testimony with my colleague, Mr. McCandless, that we are self defeating in our procurement policy in that we set the lowest common denominator for uniformity of bid and the producers are not encouraged to experiment and try to provide product beyond those specifications in terms of quality.

You say we as a Government don't have the research facilities to test new products and find out whether or not they can meet the standards that the producer suggests. How do you balance the fact that in Government we want to make certain we get our dollars' worth and not invest in some product with wild claims and something that won't do the job and still encourage this basic research into new product lines?

Mr. **Deen**. First of all, I want to say that some suppliers of this industry do improvement research, particularly in the traffic control areas and in signs and reflective materials and other areas. I am sure you may well have some of these people scheduled, so I don't want you to leave here feeling that none of the private sector suppliers do any research; some do.

But the question you ask about how to alter our system of procurement in a way that will inspire or provide some motivation for research is one we are asking ourselves, and I think it is indeed one that Dr. Belle Isle may wish to speak to. He was speaking to that problem in a suggestion of what he called "research partnerships." It is an innovative idea that we are looking at carefully and that may be one of the things we should try.

Mr. **Durbin**. If you had such a partnership, and I am sorry I missed that testimony, how would Government respond in procurement specifications to be sure that we still do get a good product even if it is from a partnership as opposed to an individual company?

Dr. **Belle Isle**. Mr. Deen mentioned that the Department of Transportation, if they would do the basic research to identify specifications to meet a need, then be able to review various product proposals that are deemed by the producer to meet the criteria, that they could fulfill their end of the bargain.

That is not that costly in terms of total effort. The research most costly is the nature of looking at various materials, bringing it from a product identification, product test and finally to a prototype where you apply it; that sequence of events for any one corporation is just too costly without consortiums of various companies working together to meet the specifications that the Department could develop and have the capabiltiy to review.

What we are saying here is that given the profit motives of different companies, they would tend not to work in a joint venture with potential competitors to jointly come up with a material that might meet the specs. So, therefore, we get the fragmentation.

I would like to suggest, however, that it would be possible if the Department of Transportation could come up with specifications around key materials and then enable the producers to see the long-term market and demand for this product, that there is going to be enough consumption of the product for everybody to get a piece of the action, nobody could do it anyway. There is no one producer that could handle the volume required.

Mr. **Durbin**. Sounds like a patent policy you are talking about where you have exclusive rights for a lengthy period of time.

Dr. **Belle Isle**. That is right. Imagine a research joint partnership in which the licensing of the patent would be shared by this consortium. There is an example of this in the computer industry. What will happen is that they will then race to the marketplace and each competing with the other ones, that technology is developed, and go through the development steps. All we are saying is that the same has to occur here where the technology and the basic material can be done through joint venture, and then let them compete in application of that material in reconstruction and repair.

Mr. **Durbin**. Thank you. Thank you, Mr. Chairman.

Mr. **Gore**. Do you know anything about something called popcorn pavement?

Mr. **Deen**. I have heard of it, but I can't remember what it is.

Mr. **Gore**. They put down several miles of it on Interstate 40 between my home and Nashville, and it is terrible.

Mr. **McCandless**. That is what I was talking about, I wasn't going to say Tennessee, but you are right.

Mr. **Gore**. They have had to go in and rip it up and put some new materials down. It was designed to let the water filter off the road surface down through the popcorn so that you wouldn't have the hydroplaning effect. More research needs to be done on that for sure.

Let me summarize this panel, or make that effort, just briefly, and I want you to tell me if I am going wrong.

We need to spend more money on research, but even more importantly, we need to organize our research efforts better and identify serious problems which now plague the research effort.

Specifically, high management turnover is a problem; lack of continuity; and an inability to focus disparate elements of the research community on large questions that have a high priority for the country.

Am I right so far?

Mr. **Deen**. Right.

Dr. **Belle Isle**. Very accurate.

Dr. **Butcher**. Yes.

Mr. **Gore**. Does it lack focus, Dr. Butcher?

Dr. **Butcher**. Could I suggest in organizing better and focusing on serious problems you leave a place for the people who are not problem oriented, but who are the knowledge builders, people who give us better understanding of the fracture mechanics for potholes, movement of moisture through soils and so on. They don't need much room, but they need a place.

Mr. **Gore**. Anybody else?

Mr. **Deen**. I think you have done well. I would add one thing, that is that we, working in a decentralized environment, it is important that this focusing and concentration we have described here not be overblown at the expense of recognizing that most of the research still should be done close to the people who are going to use it.

The problems of dissemination of what we know are enormous, and I am sure you will be told a number of times in these hearings that if we just would do what we already know, we would do better. That is true, and it is always true.

But it would be even more true if we were to focus all our efforts into centralized research, and that would be a mistake.

Mr. GORE. Do we have a way to regularly assess the research breakthroughs in other countries?

Mr. DEEN. There are some mechanisms, and one of them is the Transportation Research Board, which by the way is funded by this diverse group, literally hundreds and thousands of individuals and institutions. We operate the Transportation Research Information Service which is a computerized data bank of research going on not only in this country but around the world. We get their tapes, and we give them our tapes. They are abstracts of research going on in the past and currently, indexed by subject area so people can see what each other are doing.

Mr. GORE. Is that proving useful?

Mr. DEEN. It is useful, but I don't think it is the whole answer. The United States felt we had all the answers in transportation information many years ago, and we were ahead in most things after World War II, but there is a growing awareness that we have been passed in some areas, railroads, for example, and that we don't hold all the knowledge.

Concrete is another one. Probably we are going to have to be more looking outward and more cooperative than we have been in the past.

Mr. GORE. It certainly makes sense. It is an area where there is not a lot of competitive implications if one country has a better road system than another. But I think Dr. Belle Isle wanted to comment, and then Dr. Butcher.

Dr. BELLE ISLE. As I think about who would gain value from information dissemination about research, everybody would, the private sector, the public sector, universities, everybody. If you ask who are the people who are transferring information back and forth, it tends not to be an industry; it tends to be in universities and in the public sector.

What I am encouraging is a moving together of industry which requires some attitude adjustment on their part, but in conjunction with universities and the public sector, to say we have strategic issues, let's put the brainpower and capability we have in so we don't duplicate these things, so we don't have research going on in Government that universities could do, or Government research going on with the industry duplicating its efforts.

We need checking with each other on that, but not to check each other out.

Dr. BUTCHER. I would suggest as well as the formal structured mechanisms that Mr. Dean mentioned, there are a lot of informal mechanisms for keeping in touch with researchers on the international scene. There are meetings; professors go to meetings and come back and tell their students. A powerful way of getting the message is that way.

We have the informal structure that is loose and unorganized, but very effective. This includes the professional journals that people write in, the papers presented in conferences, and people, they meet, us going overseas, foreigners coming here, and this is backed up with data base information that we have, and this is a way we act together and act as a world community and not an isolated community.

Mr. **Gore**. Would annual reporting to Congress, Mr. Deen, on the TRB accomplishments on truly national transportation research problems, perhaps through the National Research Council and the National Academy of Sciences, help give more focus to the current research programs?

Mr. **Deen**. That is a totally new idea to me. I need to think about that. It is an interesting idea. I would like to be able to get back to you on that.

Mr. **Gore**. I would welcome a constructive response on that.

The strategic transportation research study is expected to be completed when?

Mr. **Deen**. At the end of this year.

Mr. **Gore**. The end of this year. Are any follow-on steps now contemplated?

Mr. **Deen**. When the executive committee of the TRB originally authorized the conduct of that activity, the idea was that it would begin in phases, the first phase focusing on the highway research question and later on moving to other modes. So I would expect that we may well be moving into other modes of transportation as part of that activity in the years to come.

Mr. **Gore**. Let me ask you to imagine, just briefly—and we will have to break for a vote, and this will be the end of the panel, so be brief, if you can—if you had to tick off the three or four highest priority strategic issues for research, off the top of your head, what would they be at this point?

I know your study is not complete and maybe it is not fair to ask you that question, but I want to ask all three of you, just quickly, if you could list them.

Mr. **Deen**. Start with Bill. [Laughter.]

Dr. **Butcher**. Well, as you know I deal with a broad spectrum of basic research. Give us room to move and harvest good ideas from creative people. That is No. 1, and the sole thing that is missing. All practical problems demand attention, and other problems that don't demand attention in the same way can then be neglected. It requires understanding on the part of the people who provide the funds to make sure we always have part of our research dollars available for basic research.

Mr. **Gore**. Assuming we keep a comfortable place for those basic folks and room to move and the ability to generate these new basic breakthroughs, now, what are the top problems to solve?

Dr. **Butcher**. It is really size of the individual research projects. We spend our money in too small pieces. There are big research projects that need big chunks of money. Full-scale tests, for example. You can model until you are blue in the face, but if you don't have a point of reference, you don't know if your models are any good. Therefore, the ability to make some big tests, to do big research activities occasionally. This is very important and lacking on the scene now.

I believe this is true in other areas.

Mr. **Gore**. We will hear about that from other witnesses as we testify. You have 1 minute each. Top priorities.

Dr. **Belle Isle**. I would say, Mr. Gore, long-range strategy, joint focus, continuity of that focus, clarifying the various roles for industry, government and universities in pursuing those areas, and being able to attract better talent and maintain them.

Mr. **Gore**. Mr. Deen?

Mr. **Deen**. Well, I have already mentioned the basic materials of asphalt and cement. I won't comment on that anymore.

I think a noncorrosive device to help offset this enormous corrosion bill we pay every year is a big ticket item.

Mr. **Gore**. Something other than salt?

Mr. **Deen**. There are some, yes. The problem is how we produce them cheaply enough, and there are ways they can be used that might well bring costs down.

I think the question is one of pavement management. About all we know of the question of how you design pavements and how much deterioration occurs from environmental factors versus heavy truckloads came from the several road tests done a number of years ago, and they have been repeated. They had certain deficiencies, but that is all we or the rest of the world knows about the subject. There have been many recommendations to continue long-term studies of that type, but they haven't occurred and I would say that that would be a high priority item.

Finally, the use of simulation technology to improve our understanding of how people react to changes in geometric designs of roads, pavement widths, signing and visibility markers, shoulder widths, et cetera needs research.

Mr. **Gore**. Thank you very much. This panel has gotten us off to a great start, and we appreciate it very much. We have one more panel today, but we have a vote on the floor, and those are the second bells, which means we will have to take about a 10-minute recess, and when we come back we will start up on the second panel.

Thank you, gentlemen, again.

[Recess to vote.]

Mr. **Glickman**. Why don't we reconvene now?

I apologize for missing the completion of the first panel. When they schedule things in this body, duplications are often not the highest priority to avoid. I will be here for the rest of the time.

We have our second panel which deals with the State perspectives on the issue. We have Florida, Pennsylvania, my own State of Kansas, and the State of New York represented here today.

It is a pleasure to have you gentlemen here. I think we will go ahead and start in the order that appears on the witness list. Mr. Pappas is not here, I understand.

Mr. McCue.

STATEMENTS OF PAT McCUE, ON BEHALF OF PAUL N. PAPPAS, SECRETARY, FLORIDA DEPARTMENT OF TRANSPORTATION, TALLAHASSEE, FLA.; THOMAS D. LARSON, SECRETARY, PENNSYLVANIA DEPARTMENT OF TRANSPORTATION, HARRISBURG, PA.; JOHN B. KEMP, SECRETARY, KANSAS DEPARTMENT OF TRANSPORTATION, TOPEKA, KANS.; JOHN MLADINOV, DEPUTY COMMISSIONER, NEW YORK DEPARTMENT OF TRANSPORTATION, ALBANY, N.Y.

Mr. McCue. I am Pat McCue, director of policy. Mr. Pappas is back home fighting the budget issue in the extended session of our State legislature. I thought that was an appropriate point of beginning here.

Mr. Glickman. Sure. Go ahead.

All your statements will appear in the record, so you may summarize.

Mr. McCue. To get right to the point of the testimony I would summarize my testimony by answering questions that came up in the previous panel. I thought they were right to the point.

In Florida we have some unique circumstances as compared to other members of the panel, because contrary to the argument that the system is basically in place but what we need to do is keep it repaired and maintained, we have the continuing problem of expansion along with the repairs and maintenance. We made the mistake in recent years of constantly expanding our highway system at the expense of maintenance, and the result is now we have both problems to face.

But I think both those problems need to be addressed through research. Earlier, Mr. Deen brought up the point about the AASHO road test done in 1960. It was done as I understand at a cost of about $15 million, which was an actual test. Someone said you can't learn everything from modeling, sometimes you have to go out and build a real system and drive on it to see what happens. That is what the test did back in those days, and the data that came from that test is basically the design data we still use today.

So for fairly small cost, a few million dollars, we have constructed a multimillion-dollar Interstate Highway System and other highways as well. So it points out the value of directly applied research. It also gives an answer to some of the questions that came up earlier about if highway construction is so simple, if the Romans did it and it lasted years, and the Chinese do it and it lasts forever, why can't we do that? But part of the answer is not just in materials we use but in the way we are using the system.

In China, for example, if you have a lot of pedestrian and bicycle traffic, there is no question the roads will last forever. If you had nothing but autos in this country, other than for severe weather conditions, our roads would last forever, too. We have a system designed for certain uses and we make political decisions for good economic reasons probably to make use of the system. If the Chinese had 80,000 tandem trailers in their system over in China, their system would collapse like ours.

These other gentlemen will talk about the other problems. We have heard what salt does to steel and concrete and how much savings we could have if we were to solve that. But that is not the problem in Florida. The system still falls apart. So it isn't just weather causing it to collapse.

We designed our system to the highest standards known in this country 15 years ago, and instead of lasting 20 years, Congressman Schneider, why do we need to design roads to last 20 years and we wish they would last 20 years. That is the problem. They are falling apart in 5 or 6 years having been designed for 20.

The question is why? The answer we come to is that they serve their design life. They already carried the traffic they were designed to carry. But that traffic turned out to be primarily heavy trucks. In 5 or 6 years they carried as many heavy trucks as they were supposed to carry in 20. That is not strictly an accident. We caused it to happen. We made political decisions that made it more economical to move a lot of goods by truck; and, consequently, that is the way it is done.

So we caused it to happen. That is part of the situation we should be looking at. What is the relationship between the design of a facility and ultimate use of it? You have to make that connection or you cause the problems we have had.

Another point I would like to get to is the one that Secretary Pappas is back fighting with the legislature over today, and that is the issue of alternate forms of transportation. Mr. Carney brought up the point that regardless of the ease of usage of a public transportation system he didn't intend to use one, and a lot of other people feel the same. In Florida we have come to the realization that with this phenomenal explosion in population we have increased by a factor of 400 percent the population since World War II, from 2.5 million to over 10 million. We are the seventh most populous State, and next time around we will probably be fourth.

We have masses of people moving to Florida and somehow we have to move them around. We can't afford to do it with highways, we know that. We have looked at the cost of trying to expand our highway system in urban areas, and it is phenomenal. We can't conceive of the possibility of doing that.

We found last year, for example, that it would cost the State $1 billion a year in highway construction costs just to maintain the present lousy levels of traffic service in the urban areas. Eighty percent of our urban areas are so congested that they are unacceptable from an engineering point of view, and just to keep it that bad would cost us $1 billion a year in new highway construction. So we know it is out of the question.

What is the alternative? We are trying to tell the legislature the alternative is more intensive use of what is out there, ride sharing, dedicated lanes, computerized traffic signals, all the ways to make it operate more efficiently but also public transporation. We are studying people movers and other exotic things, magnetic levitation, bullet trains, and because of this would serve Disney World we think maybe that Florida area is a better test ground than other States, because tourists might use them whereas commuters might not.

But the point is we don't know, and we can't prove that spending our money on those systems instead of more highways is really going to solve any problems. That is the argument. That is what keeps Secretary Pappas in Tallahassee today. The House agrees you can't spend that much in highways, let us put it in transit. The Senate says no way, we have no evidence to convince us that that money would be well invested. So take what we are willing to give you and spend it on more highways and do it the best you can do. The Secretary is caught in a quandary. We don't have data to prove it will work or not. So I think that that is one area that requires research, and I understand from talking to Dr. Cole prior to the hearings that that is a real point of contention, because the data you have and that I have seen and heard today shows that that is where the payoff has not been, that the lousiest research at the Federal level apparently has been in UMTA where they have tried to look into these exotic forms of transportation. I am not convinced that people movers are exotic, but simple things like that really, there has been no payoff.

People are saying let us quit wasting money on that garbage and get something that works. We need answers to that because we are in the position of having to make major investments. We raised our State gas tax and made it effective March 1, the day the Federal tax took place, so you all could take the blame. Now we have a big increase in funding. We will have an additional $500 million a year to spend on transportation in Florida.

The question is what is the best place? We know we have a lot of repair work, we can spend it all on repairs. We can spend it easily on a few new highways, or expand existing highways, or we could spend some on public transportation. We are trying to make up a mix, but we are doing it with insufficient data. We are just hoping and guessing that we can accommodate the needs of the people that are there and the people coming by coming up with this mix.

I think the way you can help us is by supporting these coordinated research efforts we talked about, or the other panel did this morning, to give us real data, data on this intermodal transfers. How many people can we expect to get off the highways and into the other systems? How much can we afford to spend on the systems to move people around?

Second, I really support what Tom Deen said about doing basic research because I can understand your frustration when you say we have been building roads for thousands of years, surely you must know something about concrete or about asphalt. But the problem is it is a combination product and when it fails, everybody points in the opposite direction. Asphalt is a combination of the material we get from the oil refineries, which is very different today than it was just a few days ago; it is not as good.

We have aggregate or rocks that go into it. In Florida the rocks are different. We use limestone and it functions differently. The people say we shouldn't even use limestone, we should import it from Georgia.

Of course someone asked about institutional problems. If you think that is not an institutional problem, tell the stone people in Florida we are going to buy our rocks from Georgia.

Mr. GLICKMAN. Your rocks will be more than in the road.

Mr. McCUE. That is right. That is why you have heavy turnover in top management. We have had four secretaries of transportation in 4 years so far in Florida. That is one of the reasons.

When you try to solve some of these problems, you darn right there are institutional problems. So realistically we say the answer is you have to use what is there. You can't get better asphalt from the oil companies, because there is no profit in it for them. You can't get the Florida Lime Rock Association to allow us to buy rock in Georgia, so we have to use the limestone and make it work in Florida.

We would like to see basic research of that type to get the most for what we put into it.

Finally, to answer the question about why are the roads so lousy, someone said because you go with low bidders and why should anybody develop better concrete, nobody will buy it. That is basically true. But if the State comes up with standards or use life cycle costing to figure out the total cost, maybe we would do a better job up front. We are trying to do that now in some of our bridges. We are not doing much on the roadway system, but we have talked about whether or not we can afford to build better roads; when we look at the cost of maintaining what we have I think what we are concluding is we can't afford not to.

We built cheap roads essentially over the last 20 years, and now we are paying the price because we can't afford to repair them. Maybe it would make sense to build better roads and bridges up front and cut the maintenance cost.

We would like to continue being the leaders in that technology. We have taken a lot of criticism for it lately. We have built unusual bridges. We are going with new techniques for construction in bridges. To answer the earlier question, we ran into a lot of people. The suppliers didn't like it, the labor people didn't like it; you name it, they didn't like it. Because it was a new technology, promised to save a lot of money. But it was foreign, new and different, and they didn't want to do it. When we forced it in a few areas in major bridges, we saved a fortune. We are satisfied that it was a good approach.

One mistake was we didn't look to see what it would maintain. Our feeling now is that it will be cheaper, that the maintenance cost will also be less than the original construction cost, but it takes different equipment, takes training, takes a whole different approach to the maintenance problem. And once again people are coming back to us and criticizing us for taking the lead in technology.

We have to have some support in taking a few risks if we are going to do a better job. That is the message basically. There is knowledge out there. You can support it and help us use it. It is just that as public agents we are subject to severe criticism, first of all, for making a mistake and, second, for doing something that is more expensive up front even if it has the potential for saving money later on.

So with your support and good evidence, that is really what we look for from this committee, if you support research that gives us evidence so we can walk into the legislature and say here is proof that what we are offering is really better, really in the public interest, then I think they will pay attention. But if it is only opinion, they can get that anywhere.

Mr. Chairman, thank you.

Mr. GLICKMAN. Those were very responsive comments. Thank you.

[The prepared statement of Mr. Pappas follows:]

PREPARED STATEMENT OF P. N. PAPPAS

Mr. Chairman and members of the Committee:

My name is Paul Pappas. I am Secretary of the Florida Department of Transportation. It is a pleasure to appear before you and express our thoughts, from the state perspective, on the current condition and the anticipated future of Florida's transportation systems.

It is very timely that the Congress address itself to the nation's transportation infrastructure - the fixed facilities and equipment which are in place to provide mobility to the citizen as well as carry goods to the users. We in Florida have only recently documented the severity of our problems with our existing transportation infrastructure. The high costs associated with restoring the structural integrity and operational efficiency of our systems accumulated in a surprisingly short term.

Florida's rapid development contributed heavily to this deterioration. During World War II, Florida placed about midway in national population ranking with fewer than 2 1/2 million residents. Today, we have more than four times that number. We are now the seventh most populous state in the nation and by the next census we expect to rank fifth.

Reacting to this rapid development in population along with unprecedented growth in tourism, we have focused our attention almost exclusively on the expansion of our transportation systems. Many of our highways were widened and reconstructed before they deteriorated from wear and tear.

For many years, the financial resources that supported this expansion grew at a dependable and predictable rate. The carrying capacity of the land seemed unlimited, fuel was plentiful and inexpensive, and the mood of the state was for full speed development and economic growth at the fastest possible pace.

During this period the mobility of the average citizen grew at such a rate through private automobile ownership that we were content to allow railroad service and urban bus systems to recede or disappear.

So, we approached the 1970's with little concern that the state's rapidly expanding urbanization signalled a change in the ground rules and that complete reliance on one mode of surface transportation, the auto for people and the truck for goods, was an incomplete and vulnerable strategy.

During the seventies, several thoughts began to command the attention of transportation planners.

1. Energy intensive transportation has no long-term future.

2. Transportation user fees based on fixed cents per gallon are no longer dependable or reliably predictable.

3. Urban areas cannot accommodate unlimited numbers of private automobiles.

4. Not all citizens are served by highway-based transportation systems.

5. The carrying capacity of the land is finite.

6. Surface arteries which cannot be expanded due to high costs or physical constraints must still be rehabilitated periodically to remain serviceable.

7. The useful life of many of the facilities constructed during boom times is expiring and a significant reconstruction program is accruing.

Despite the concern of planners, our backlog of accruing needs grew alarmingly through the 70's and early 80's until the spring of 1983, when the desparate need for increased financial support for transportation was recognized by the Congress and the Florida state legislature. In Florida, these combined new revenue sources total more than $400 million per year, yet they are sufficient only to prevent structural conditions from worsening and to slow the growth of traffic congestion. At best, the backlog of existing structural deficiencies will remain constant and the pace of new highway construction will be far slower than the projected growth of traffic and the need for expanded facilities.

Today, of the more than 34 thousand lane miles of road on our state highway system, one-fourth are structurally deficient and one-fifth are operationally deficient. In terms of current dollars, structural rehabilitation (resurfacing and reconstruction) of our most deficient highways would cost $400 million. If operational deficiencies are addressed as well, another $6 billion will be required. These costs represent the estimate of needs to cure existing problems, not costs anticipated to accrue over time. Nor is this the whole story. There are also substantial bridge needs. To replace and rehabilitate the bridges on our system that need work today would require another half billion dollars.

As you can see, Florida has its share of problems with the transportation infrastructure in the highway mode and we have not even discussed our needs in transit, air, and rail. Obviously, total transportation infrastructure needs far exceed any reasonable level of anticipated resources.

Given that this is the case, the challenge I see ahead for those in the transportation industry is to select those research areas and those individual research and development projects which promise the greatest potential return as we enter the twenty-first century. There is no question that the repairs of those facilities which are to be a part of the continuing highway network are of prime importance. However, before we undertake this work, we must be certain of two things:

1. The facility being reconstructed is in keeping with the needed future level of services, and

2. We will incorporate all available, economically justifiable technological advances to optimize our investment in the reconstructed facility.

To meet these two conditions, it is readily apparent that the results of appropriate research and development can greatly facilitate our policy and investment decisions.

For example, extensive study of engineering economics and system economics could be very beneficial. We should know and appreciate the factors involved in increasing the normal life cycle of a structure from 25 to, say, 100 years. It is certainly possible that the utility of some bridges, for instance, would be exhausted after 25 years in a dynamic state such as Florida. Alternatively, there are applications for facilities such as the Brooklyn Bridge which continues to be serviceable after 100 years. Another facet of economics which has received too little attention is the concept of cyclical spending. Government should seriously analyze whether off-peak timing of major public works investments can reduce costs while serving to defray hardships on individuals during periods of economic stagnation. A national policy of planned "surges" in infrastructure investment over and above the continuing program levels could serve some very worthwhile and essential public purposes.

One mechanism which the Congress has used over the years to evaluate certain new or untested concepts is the authorization of demonstration projects. There are times when the best laboratory is out in the real world.

A true demonstration project is one which does not simply replicate ideas which have been tried in other areas, but which is genuinely innovative in nature, having the potential to serve as both a laboratory setting for controlled study and a readily usable public facility providing an immediate and measurable return to the citizen.

In Florida, we have a number of such demonstration concepts which could be activated in a fairly short time. For example:

1. A system of exclusive truck lanes to be constructed as an adjunct to an existing controlled access highway between two major urbanized areas. This would permit study of:

    a. enhanced safety of traffic segregation,

    b. actual pavement damage attributable to heavy vehicles, and

    c. a comparison of true costs between directly competing rail and truck service.

2. A high speed rail network between several major tourism and business centers. This would serve to demonstrate the viability of fast passenger rail service in densely populated, highly travelled corridors in this country. It would also tell us what we can expect in the way of environmental impacts, both positive and negative, what future we can expect of electrified transportation, and how much highway traffic is diverted to rail, reducing the need for more highway expansion.

These are but two of the several opportunities before us, but they represent investments in real things that are of tangible benefit to the citizen. We have often heard the concern expressed that much of our research is so esoteric in nature that it seems to be serving the needs of the researcher only and has no obvious near-term application. Therefore, we must strike a reasonable balance between pure research and applied research.

Over the years, the Florida Department of Transportation has actively pursued additional knowledge in a laboratory setting through its Bureau of Materials and Research. This centralized research function carries out investigations to support the development of new specifications, materials, processes, and procedures as well as serving to test construction materials used on the site to assure their compliance with design specifications. The expenditures associated with the operation of this function are expected to exceed $10 million this year.

These examples give evidence that we understand and appreciate the necessity of scientifically conducted research to back up the work we do in the field. There can be no question that beyond the applied research discussed aove, pure research is also a necessity if the United States is to remain in the forefront of technology and we strongly support the continuation and expansion of pure research activities.

For example, we believe that major advancements can still be realized through scientific analysis of the basic properties of materials used in construction of transportation facilities. I'm talking about materials as common as cement, asphalt and the aggregates mixed with them to construct highways. The properties of asphalt, in particular, have changed dramatically as a result of alterations in the refining process reflecting changes in world uses and prices of oil byproducts.

We are also interested in research in areas of intermodal tradeoffs which will help us determine the potential effectiveness of substituting transit facilities or ridesharing and transportation system management projects to replace highway expansion plans which have become prohibitively expensive and economically and socially unacceptable.

The Florida State Legislature has expressed a strong interest in the establishment of a Transportation Research Center at one of our State universities. This activity would be staffed with ten full-time professionals and have an initial budget of nearly $1 million. It would serve to provide added basic research into the current problems of transportation facility development and provide independent ideas and evaluations of new processes and materials.

These few examples illustrate the very broad research areas that need to be addressed and some activities currently underway or planned to support our increased expenditures in transportation infrastructure construction and rehabilitation. Our comments are obviously not all-inclusive but hopefully, they serve the purpose of demonstrating the importance of research as a very vital link in the infrastructure chain.

Thank you for providing me the opportunity of sharing these remarks with you today.

Mr. GLICKMAN. Mr. Larson?

Mr. LARSON. Thank you. I am pleased to be here. I have enjoyed the comments this morning, and in particular I have enjoyed being here in this room and looking and thinking about the implications of what I see on the walls around me, that one of the people this morning at least referred obliquely to the comment if we can put a man on the Moon, why can't we—and you fill in the blank—have sewer pipes that don't break, and bridges that don't fall apart.

I would offer there are very, very good reasons for that, and one of the reasons, again looking at the pictures here, is that while we know a little about the harshness of the Moon surface very few people know how harsh a road surface is. Someone continued on the bridge that develops new potholes, I would suggest if we took the time to measure the environment at the road surface, you would see it is harsh or harsher than on the Moon or anywhere else you can imagine.

It is subject to pressures, temperatures, abrasions, and a variety of things that make it an extremely hostile environment, and so I would submit that getting to the Moon and walking around there may indeed be far simpler than fixing a road surface in a way it will last in the way it is there.

We are talking about new ideas really. I think everybody knows that new ideas die unless they have an advocate. Mr. Kennedy was the advocate that clearly made all these photographs possible. He stayed with it for a long time and established it. Most other new ideas, especially in a low tech environment, which is what we are talking about here, don't have good advocates, so they die even though there might be a lot of them that are important.

My background is perhaps something worth commenting on. Just by way of information, I spent most of my working career as a university researcher at a university research institute for the last 4½ years, and that is a long time, as we have heard, in government; and I have been secretary of transportation for the State of Pennsylvania. I was a producer and now I am a consumer of the subject we are talking about. These hearings are timely from our perspective because in Pennsylvania we are spending hundreds of millions restoring infrastructure.

This summer, for example, we will spend more than $150 million on Pennsylvania interstate highways. We also believe in the value of research, and we spend about $3 million a year on research and more than 70 percent in the area of infrastructure rehabilitation. So we believe in the subject and that is why I am here, really.

I would like to commend on the points made, but I will go quickly through my testimony and highlight a couple points.

The adequacy of research has been spoken to and clearly funding is inadequate. The small fraction of 1 percent is just not able to do justice to the subject even if you had ideal organization. Organization is a problem but funding is a problem as well.

Management of research has been touched on, and I couldn't stress too strongly the faults and foibles of management since I am a manager myself, and I can tell you for sure that it was 2 years before I could ask questions about research in my agency. Looking at DOT, the average tenure is 2 years, so any responsible secretary will never get to R&D simply because operational problems will subsume him for 2 years.

So I would say the management at the highest level is a critical problem, and I can't do more than identify that. But there are management problems within the research community. One of the problems is that it is an old boy's club, whether you go to ASTM or National Science Foundation or Transportation Research Board, or wherever, you go to the committees and organizations that are responsible for much of the innovation you will find that Congress, of course, is blamed for being the ultimate old boy's club, but the research community would be an equal or top it.

You don't have new ideas coming out of these groups because seniority plays too large a role.

Mr. GLICKMAN. Old boys but not good old boys.

Mr. LARSON. When it comes to good ideas you have to have good new boys to overpower the good old boys, and that doesn't happen in the research community very often.

The question of scope, there has been reference made to the strategic research study of the TRB. I am chairman of that effort. I think that that is an unparalleled effort in terms of what it is trying to do. It is trying to look at the high potential areas and say how can we put together the change in the process that allows us to have impact? I can't speak to what will happen because the process is underway.

I think it is a very—has a high potential for success. The key element in all this really in terms of making things happen would be to somehow find a way to get the profit motive into research. We have not done that. Clearly it involves procurement, involves a lot of things, but we have to be able to find profit in research or we are not going to see the product that we would like to see.

In terms of institutional arrangements, we have seen a good deal of the highway-related research in two institutions or groups of institutions. One is the university through the various civil engineering and related departments, and the other is in the Federal Government and the State governments as they relate to the Federal Highway Administration, particularly.

In the universities we have fragmented, too. We give out small amounts of money, and I suppose there is an equity issue that drives Congress and any bureaucracy but we throw out the bits and pieces and we train one masters degree student and he writes a thesis that is probably inconsequential and goes on about his business and we multiply this by hundreds and thousands and really don't get much product.

If the Federal Highway Administration—we have had good research there and now we have invested in a large reserve laboratory over at Fairbanks, but I see every reason to be concerned because of the management turnover I have spoken to.

You can't put together a good research program in 2 years and you can't have long-term impacts unless you have more continuity than that.

Applied versus basic research, that is something I care about because I was in the university setting. I don't know for sure how you manage the basic research that needs to be done. Clearly we want, and politicians, too, want big hits, headlines, and you don't get these out of the basic research investments.

What I would say is that if we take everything down to the short term as we are inclined to do in this country, we can guarantee there will be no new technology on the shelf that we should be drawing on as we move along in time.

Some areas where long-term multidisciplinary research is needed and maybe it is basic, maybe not, that is a word that is hard to define; clearly the ones Mr. Deen mentioned, Portland Cement, devising chemicals and new structure approaches, these are areas where the payoff, I believe, would be enormous.

So, to sum up, there are a variety of problems, that we face. There are managerial problems, institutional problems, and financial problems, and all of these must be addressed if we are going to see the kind of impact that we can see demonstrated by these kinds of efforts applied properly on the walls of the room we are in now.

Thank you.

Mr. GLICKMAN. Thank you, Mr. Larson.

[The prepared statement of Mr. Larson follows:]

PREPARED STATEMENT OF THOMAS D. LARSON

I'm pleased to offer testimony before the Subcommittee on Investigations and Oversight and the Subcommittee on Transportation, Aviation, and Materials regarding problems and prospects for research in transportation infrastructure, especially highways and bridges. My name is Thomas D. Larson. I am the Secretary of Transportation for the Commonwealth of Pennsylvania. I have held this position since January of 1979. Prior to that time, I served as Professor of Civil Engineering and Director of the Pennsylvania Transportation Research Institute at the Pennsylvania State University. In this capacity, I was a producer of research fully conversant with all aspects of that business for many years. And now for the past four-and-one-half years, I have been primarily a knowledge consumer and an executive responsible for assessing the adequacy and the appropriateness of the research producing such knowledge.

These hearings are timely. From Pennsylvania's perspective, we are in the midst of a major infrastructure restoration process that will consume hundreds of millions of taxpayers' dollars. The responsibility for making sure that such funds are used in the most cost-effective fashion possible is one that we take very seriously.

I will speak first to the adequacy of research in view of the current focus on maintenance and restoration, specifically treating funding, scope, organization and direction. I will then speak briefly to the mix of applied and basic research in the areas under consideration.

To sum up then, on adequacy of research, we probably have an inadequate level of research to support the emphasis that the Congress has placed on the maintenance and rehabilitation area. Let me speak to the several subcategories of adequacy.

Funding

As Chairman of the Transportation Research Board's Strategic Transportation Research Study, I can tell you that highway transportation research is being funded at a lower level than one can find in even the most non-technologically oriented industries in America. A small fraction of one percent of the total expenditures is dedicated to research. One can state without serious fear of contradiction that we are underfunding research in highway transportation.

Scope

As I have said earlier, we have not looked carefully at research in maintenance and reconstruction. And so it is highly unlikely that we have developed a scope of research appropriate to the level of activity that we will be seeing in the years ahead. The Strategic Transportation Research Study that I have just mentioned is working to develop a scope of research appropriate for the 1980's.

Organization

Transportation research, in particular highway transportation research, has had its principal foci in the federal government (the old Bureau of Public Roads, and more recently, the Federal Highway Administration) and in continuity to the programs assigned to federal research laboratories. And if this problem cannot be solved, then it was a serious error to provide the new facilities that have, in fact, been provided.

While the private sector has not played a major role in past highway research, we should mobilize a for-profit arm to our plan. This probably requires a major re-direction of government procurement and other factors beyond my expertise.

Direction

The principal difficulty with highway research that has a maintenance emphasis is in understanding and agreeing on direction. There are an infinite number of topics for research. We must find those topics that account for the largest part of our transportation investment and focus our attention there with enough time and enough money so that results can be realized. This again is a major thrust of the Strategic Transportation Research Study that I have spoken about earlier.

APPLIED AND BASIC RESEARCH

As a former university professor, I am acutely aware of the desire among university faculty to conduct basic research. It is from basic research that advanced graduate students find financial support and it is from such research that professors can publish papers in scholarly journals. Basic research provides the "seed corn" for numerous practical innovations. While basic research is often decried by administrators, and indeed I have reduced emphasis on basic research during my own term in office, I'm here today to argue for research to solve this problem has been underway, but certainly with nothing like the kind of attention that it should have, given the magnitude of the problem. I could cite other kinds of examples, but these are maintenance-related issues at the low end of the glamour spectrum and have not received the attention that is deserved.

Thank you for allowing me to come before you and to express views that in part represent my background as a professor and in part my experiences as an administrator responsible for the fourth largest highway and bridge network in the country--and the only one of the four large systems that has the winter maintenance problems specific to Pennsylvania. I will be pleased to answer questions or to provide follow up comments if this is necessary or desirable. Thank you.

Mr. GLICKMAN. It is a pleasure to welcome my friend John Kemp, who runs the road system and other transportation systems in Kansas and does a superb job. It is a pleasure to have you here, John.

Mr. KEMP. Thank you, Mr. Chairman and members of the committee. I am pleased to be here. I will take more from this room than what I leave here. It has been enlightening to listen to the first panel and the interchange of thoughts and ideas.

I think what is so important about the infrastructure is basically its importance to mobility, to safety, to health, and to our economic well-being as a Nation.

I have summary remarks I have prepared and I will race through these and then be available to answer any questions that you might have.

Of course, pure water, safe bridges, and all that is very important to us individually, but to business and industry, an infrastructure is absolutely essential. You can't get a plant to move into a community in Kansas unless you have a good water supply, unless you have a good infrastructure in general. Yet, we have declining investments in the infrastructure and it is wearing out a lot faster than we are replacing it with.

Of our approximately little over half million bridges in the nation, 45 percent are either structurally deficient or functionally deficient. I think that the important matter of that is, even more important than the number, is that the number of deficient bridges is expected to increase in the future.

That is attributable to the fact in large part that 37 percent of the bridges were built in the period of 1940 and earlier. Kansas has 4.4 percent of the Nation's bridges, but we have 5.9 percent of the Nation's deficient bridges. The price tag on the bridges alone is about $47.6 million and that is just really a drop in the infrastructure need bucket. The associated general contractors have estimated that it would take $3.03 trillion to save our backlog of infrastructure needs at this time.

About 60 percent of that is in the transportation area or $1.8 trillion dollars, and highways alone have $1.6 trillion of that figure, which is over half the total.

I would like to turn to some of the more significant problems dealing with infrastructure and research and share with you some things we are doing in Kansas to make our dollars go further.

I think that the first issue I would like to address is the need for adequate research into exactly what our infrastructure crisis is. I think in the highway area in particular we have had a better handle on what needs are and how we measure them than in other infrastructure areas. In the fifties and sixties where we went through a period where probably every State had a needs study. I believe we have a better handle than what there is in water, sewer, hospitals, libraries, jails, you name it, whatever else is in the infrastructure.

It seems that it would be terribly important for the Federal Government to get a handle first on what is the infrastructure problem before we start to move into a program of funding it.

I would point out that in development of any needs estimates, it is very important to develop standards from which you measure those needs. We have probably a better handle on that highway field more than any other place. A related issue is the relationship between transportation and economic development. We might say what are those relationships? What is the direction of the future economic growth? If massive heavy industrial development is of the past, then should we continue to build a highway network capable of supporting that type of economic growth.

Certainly research is necessary and if you read some of Toffler's Work in the "Third Wave", and "Megatrends" by Naisbit and others, there is some indication that we might be entering into a different type of society, an information society where perhaps some heavy manufacturing would be done in Third World countries or elsewhere and instead of our highway system serving as part of our assembly line for production in America, we may be only a distribution system where the products come in their final form. But somebody ought to look at that before we embark on an infrastructure financing program of some kind.

Research should include macroeconomic level research that attempts to address the appropriate mix of transportation modes. This is what Mr. McCue of Florida has addressed. It should look at what the future development of the United States will be economically. It should be something that attempts to assess the current inventory of public works and that will attempt to determine the disparity between that which is needed and what we have.

I think it is important to say that the private sector spends something like 2.3 percent of the gross national product on research where in the transportation area, we are at around two-tenths of 1 percent.

Let me cite an example of what we have done in Kansas that makes best use of what we have now. I don't think we can throw everything away and start building again. We must capitalize on what we have. We heard the terms earlier of rehabilitation and repair and retrofit. I think those are terribly important.

Between 1955 and 1965 in Kansas, we built many bridges on our highway network by using two girder continuous reinforced concrete construction. When our inspections revealed shear cracks present in some girders that could result in failures, we decided to investigate and repair techniques rather than go the route of tearing down the bridges and building new ones. With a budget of only $50,000 to start, we began research in 1976 on a repair technique called post reinforcement.

We had developed a technique that we call rebar insertion that consists of locating and sealing all of the girder cracks, vacuum drilling small diameter holes through the deck into the girders at a 45 degree angle 8 or 9 feet deep, then we fill the holes with epoxy and insert reinforcing bars in them.

The epoxy bonds the reinforcing bars to the concrete in effect and makes the bridges stronger than they were initially.

We have through an investment in this regard of about $100,000 realized savings of well over $1 million.

We have about 80 of those bridges in the State. We are in the process now of revising and strengthening those bridges. We started out with our maintenance forces to do it and we have gone to the contract method now which is the proper way to do things.

Another area we have done research in that Mr. McCue mentioned is the limestone issue. We have that same issue in Kansas. We can find better rock but we have to go to Colorado or other places to get it. I can tell you that is mighty unpopular.

Through research we did in the last 3 or 4 years, we have revised our specifications for the kind of limestone that we will allow to go in our Portland Cement concrete in order to avoid the deterioration and cracking we were getting at the joints.

We found through working closely with our limestone producers that there were ledges of limestone in our deposits that would produce the kind of aggregate we wanted. The issue related to absorption of the aggregate and as much to the rate and the amount. By working the ledges, we can meet the specifications with the limestone in our own state with our own producers and we are satisfied that this will have yields much in excess of the million dollar return on the $100,000 research investment that we have mentioned.

I do not promise you a million dollars on return on every $100,000 of investment in research. That is not the nature of it. We have a need for better deicing materials. We need good patching materials that can be used by everyday maintenance people in the field. We have excellent polymer materials, but a lot of those materials are highly explosive and it takes almost a technician that is in laboratory conditions to work with it.

So we have to bring these down to situations that are functional.

Now, to just summarize, we have to first make the best use of what we have through repair, rehabilitation, and retrofit.

I think we need to do some macroresearch and find out what it is we want in the way of an infrastructure, what type of society are we going to serve, what type of economic development are we going to serve. Then I think that we have to evaluate our infrastructure in terms of common measures so that every State and unit of government will be treated the same because ultimately in any of these programs, especially if they are through the Federal Government, money is passed out in accordance with a measure of relative need.

If we don't measure that on a common basis, we have real problems.

Thank you, Mr. Chairman. It is a pleasure to be here. I will be glad to answer questions.

Mr. GLICKMAN. Thank you, John.

[The prepared statement of Mr. Kemp follows:]

PREPARED STATEMENT OF JOHN B. KEMP, SECRETARY OF THE TRANSPORTATION, ON PROBLEMS OF AND PROSPECTS FOR RESEARCH IN TRANSPORTATION INFRASTRUCTURE, ESPECIALLY HIGHWAYS AND BRIDGES

Mr. Chairman and members of the subcommittee, my name is John B. Kemp. I am the Secretary of the Kansas Department of Transportation. You have invited me to testify today concerning problems of, and prospects for, research concerning the transportation infrastructure, especially highways and bridges.

I shall begin by noting that more and more people all over America are hearing the term "infrastructure" and the phrase "infrastructure crisis". This word has become one of the newer and sexier words used for describing the problem with public works.

What is so remarkable about our public works infrastructure is its importance to our personal mobility, safety, health, and economic well being. We all depend upon good roads, safe bridges, pure water, ample energy and healthful sanitation. To business and industry, the infrastructure is more than beneficial; it is fundamental to their existence.

Yet, we are experiencing a pattern of declining investment which has contributed to an extended period of deferred maintenance to the point where our public facilities are wearing out faster than they are being repaired or replaced. While I, as a citizen, have an interest in all public works and all parts of the infrastructure and appreciate the interrelationship between the various parts, I am here today to talk to you about problems in one particular part of the infrastructure—highways and bridges.

STATUS OF BRIDGES AND PRICE TAG

By way of example, let's consider the status of the nation's bridges using figures presented to Congress in the Third Annual Bridge Replacement and Rehabilitation Report. That report indicates that 248,527 of the 557,616 bridges in the nation are either structurally deficient or functionally obsolete. This in itself is alarming; a source of even more concern is the fact noted in the report that it is expected that the number of deficient bridges on the Federal-aid system will begin to accelerate in the near future. The report shows that nearly 206,000 or about 37 percent of the nation's bridges were built in 1940 or earlier. Many, probably most, of these bridges were not designed for today's axle and gross loadings nor for the volume of traffic using them.

Kansas has 4.4 percent of the nation's bridges but 5.9 percent of the nation's deficient bridges.

The price tag for rehabilitation or replacement of the nation's deficient bridges as outlined in the report cited above is 47.6 billion dollars. This was reported in 1982 and was based on 1981 data. In May 1983 the Associated General Contractors reported the nation's bridge needs to be 51.7 billion dollars. This would tend to indicate that the needs are rising faster than we are making needed improvements.

And yet, that 47.6 billion dollars to replace or rehabilitate deficient bridges is but a drop in the infrastructure need bucket. The Associated General Contractors estimated the minimum essential investment in our nation's infrastructure at 3.03 trillion dollars with a current annual shortfall of 104 billion. Nearly two-thirds of that, or 1.8 trillion, is for transportation; 1.6 trillion is for highways and bridges. The numbers become mind-boggling.

INFRASTRUCTURE AND RESEARCH

It is interesting in light of these data and these proceedings to note the testimony of Dr. A. F. Woods at the proceedings of the 8th annual meeting of the Highway Research Board in December, 1928. Dr. Woods noted that the 52nd Congress in 1983 decided that the time had come to see what could be done to redeem the roads of the country after a half century of neglect. It is most interesting that Dr. Woods reported that the Congress called upon the Secretary of Agriculture to do four things: (1) to make inquiries in regard to the systems of road management throughout the United States (2) to make investigations in regard to the best method of roadmaking; (3) to prepare publications on these subjects; (4) to assist the agricultural colleges and experiment stations in disseminating the information obtained. 90 years later we are here attempting to discover exactly the same things. What is the status of the nation's infrastructure? What can we do about it? How can research help?

Let's now turn to what I see as some of the more significant problems dealing with infrastructure and research and share with you some of the things that we are doing in Kansas to make our dollars go further. The first issue I will address is the need for adequate research into exactly what our infrastructure crisis is. In transportation during the 50's and early 60's most states, either on their own or in participation with the federal government, launched a series of highway studies to determine how much money would be required to build adequate highway transportation systems. Methodologies used in these needs studies are used by many states today.

However, many of my colleagues and I have learned that our legislatures are unwilling to listen to numbers of the magnitude generated by such studies. Instead, we are to look at alternatives—that the needs studies done during the period of massive new construction of new highways are inappropriate for now and for the future. Indeed, your own Congressional Budget Office frequently publishes studies outlining less expensive options for you to consider in the funding of our nation's highways and bridges. These options often include lesser levels of service.

ECONOMIC AND POLICY ISSUES

A related issue is the relationship between transportation and economic development. The national interest and concern about our economic competitiveness and general future prosperity have grown to the point where large capital improvements can only be justified in terms of economic betterment. But what are those relationships? What is the direction of future economic growth? If massive heavy industrial development is of the past, the should we continue to build a highway network capable of supporting that type of economic growth? Research is necessary.

This also brings us to a public policy question of how is economic development to occur in the United States and more importantly in the 50 very different states? In Kansas, our Governor has made a commitment to the growth of high technology industries. Clearly that signals the need for development of transportation facilities other than massive highway networks capable of carrying heavy traffic volumes. But, we in Kansas will continue to serve the world as a provider of grain. Thus we continue to need the transportation network capable of moving that grain. The choice for a triple based Kansas economy consisting of our grain market, our aircraft industry, and our commitment to high tech. will not be the same for all other states—each has its particular needs.

Infrastructure research to us then, involves macro level research that will attempt to: address the appropriate mix of transportation modes for the future economic development of the United States; assess the current inventory of public works, determine disparity between that which is needed and that which we have; and, suggest how to eliminate that disparity.

These are the weighty issues for long-term infrastructure development. I assure you, however, that there are many "minor problems" that can be solved much more easily and much more quickly. I would also like to point out to you that there is a paucity of funding for research in the transportation field and the transportation research funds we do have often come at the expense of the capital improvement programs. The private sector spends approximately 2.3 percent of the Gross National Product on research. In the transportation sector that appears to be about two tenths of one percent.

However, it is difficult for the states to allocate even more to research. In these times of tight budgets, state legislators often want tangible results today; they are less impressed with the promise of better things tomorrow.

KANSAS RESEARCH EXPERIENCE

It is clear, however, that funding for research is absolutely essential to stretch the capital improvement dollar. In Kansas, we have found that we accrue construction savings ranging from $1.30 to $1.50 per year for every dollar that our research unit spends in developing new procedures and practices.

For example, between 1955 and 1965, we built many bridges on our highway network by using two girder continuous reinforced concrete construction. When our inspections revealed shear cracks present in some girders that could result in failures, we decided to investigate repair techniques rather than go the route of tearing down the bridges and building new ones. With a budget of $50,000 provided through the Highway Planning and Research Fund, we began research in 1976 on a repair technique called post reinforcement. We developed a technique that we call "rebar insertion" that consists of locating and sealing all of the girder cracks, vacuum drilling small diameter holes at a 45 degree angle 8 to 9 feet deep, filling the holes with epoxy and inserting reinforcing bars into the holes. The process makes our bridges stronger than when they were first built. We calculated a return of more than 1.1 million dollars on our research and development investment of less than $100,000. We have more than 80 bridges on which this rebar insertion method can be used. We have no way of estimating how much can be saved nationwide through the use of our rebar insertion methods.

FURTHER RESEARCH NEEDS

I certainly don't mean to imply to you that every $100,000 spent will yield 1.1 million dollars, but there are countless other problems to be solved that offer the promise of savings. Winter bridge safety demands the use of materials to deice. However, cheap material such as salt deteriorate the bridges. Materials that will solve the problem without causing deterioration are prohibitively expensive.

Good patching materials need to be developed that can be used by everyday maintenance people in the field. Excellent polymer materials have been developed, however they require special handling.

In addition to research on physical properties, we need cheap efficient means of measuring and forecasting traffic and the impact of changes in the dimensions of that traffic. The Congress recently made provision for changes in truck weight, width, and lengths on many of the nation's roads. You mandated the opening of certain roads and encouraged the opening of others. But, you did not tell us what the impact was going to be of those changes. Do you know? How should we prepare? Research in the area is absolutely essential.

You have asked me to comment specifically on the funding, scope, organization, and direction, of present federal and state transportation research. Funding is less than adequate. More savings are possible from more research dollars, but do not increase research funding at the expense of capital improvement funding. That would be to increase current need in one area to solve the need problem in another.

The scope of research must be expanded to include the macro level issues facing the country in terms of economic development and the appropriate infrastructure to move toward the twenty-first century. Clearly the transportation area is vital. I would like to suggest that the scope of research be expanded to include these. Begin with a national inventory of carefully defined needs—needs defined in the context of a public policy analysis of the direction of development of the nation's capital infrastructure.

At the same time, increased research must be done in the materials area so that we can continue to stretch our highway and bridge dollars. In my opinion, the current federal/state relationship in research works well and should continue to work well in the future.

Mr. GLICKMAN. Our last witness is the representative from the New York State Department of Transportation, Mr. Mladinov.

Mr. MLADINOV. Thank you, Mr. Chairman. I can endorse much of what has been said here today. I think we have much in common as to our perception of the problems, both as to problems relative to research needs as well as problems we are faced with with our infrastructure.

New York probably experiences problems before the rest of the country because we are an older State, we have a higher density and older facilities. In many cases, we may be at the forefront of experiencing the problems and in some instances we are at the forefront of attempting to turn program direction around and at the forefront of research in attempting to solve the problems that we are confronted with.

We reoriented our highway program in the early seventies from a program aimed at constructing new facilities to a program that was aimed at keeping in place the facilities that we had already built.

We do have basically an old infrastructure. Someone this morning commented on the Brooklyn Bridge as being 100 years old. It also took 17 years to build. We are celebrating its 100th year but there is no mention of the fact that we are putting $100 million into rehabilitation of that bridge. The cosmetic rehabilitation is done that gives it the appearance it has today. It was beautiful for its celebration. That work was only a drop in the bucket as to what the total cost is going to be.

Fortunately, we find we are not going to have to replace the main cables. We only have to replace some suspender cables. The anchorages and anchorage attachment members need substantial work. That is ongoing and will be going on for a good number of years.

It was possible to build a structure that would last 100 years and we can keep it going for another 100 years with sufficient investment in it.

We can do that with new facilities as well.

The other States in the Northeast also, and most States, have reoriented their programs to keeping in place the facilities they already have. You heard from the State of Florida. There and for those States similar to Florida, the continuing growth of population and continuing increases in traffic volumes, dictate construction of new facilities as well as maintaining those in place.

When it comes to maintenance, what I heard this morning reminded me of an experience that I have had in the State of Washington where I was before I joined New York State. Very early on in the interstate program, we had a GAO review of our interstate cost estimate and our interstate decisions. We were criticized for the fact that we were using Portland Cement concrete for the interstate highways going over the mountain passes. We used Portland Cement concrete even though it was a higher first-cost facility because we required chains in the wintertime to get over the mountain passes.

Chains chew up the asphalt concrete so it has such a short life that our policy decision even before the interstate program was to use Portland cement for the highways over the passes.

We were criticized for the higher cost of using Portland Cement in the first instance and we were told that instead of "gold plating" the interstate system, we ought to go for the cheaper first cost material and the State could simply fund the increased maintenance cost associated with the cheaper materials through the years.

That was called the "Anti-Gold Plating Act of 1958," I believe. But that is something that we were rapped with at the beginning of the interstate program and most of the States lived with the same consequences.

Only the first cost of the facilities was a Federal concern but the cost of maintenance was not a Federal concern, and it continues not to be a Federal concern.

We were successful through the years in getting, first with language in a House Public Works Committee report, later in legislation language modifying the definition of construction so that Federal aid could be used for activities such as resurfacing and reconstruction, which they could not be used for before.

That became the 3-R program and more recently the 4-R program. So there has been a reorientation on the part of the Federal legislation, reorientation of the position of Congress and the Federal agencies as to what is an appropriate role for the use of Federal funds to begin with.

It is a condition that we in New York were faced with probably ahead of other States in the country.

Most maintenance tasks are highly labor intensive, as was mentioned earlier. Yet the methods that are being used today are virtually identical to those of many years ago. Granted the manufacturers of equipment have produced equipment that permits a much higher level of productivity for some tasks and there are new materials and improved materials used for maintenance purposes.

By and large, however, the maintenance activities today, and the materials used and the methods used, are essentially those of 30 or 50 years ago, with some reduction in the labor intensiveness necessary because of improved equipment that is now available.

Yet, there is a minimal amount of research that is being conducted in the maintenance area. The so-called federally coordinated program of highway research and development shows that only about 1 percent of the research that is being conducted within that program—and that includes the HPR activities of the various States, the National Cooperative Highway Research program, the contract research by the FHWA and inhouse research by the Federal Highway Administration—all of those combined, only 1 percent of that total activity is related to maintenance research according to FHWA reports.

In addition to the concern about materials and methods, there is also a need for research and improvements in maintenance management as well.

There is a very large payoff that is potential in both of these areas. A very large portion of the funds going into our highway plant are associated with maintenance. More than half the total personnel in our Department of Transportation are maintenance personnel.

So there is a very high cost associated with that and a very high potential payoff from improvements.

One of the other aspects mentioned this morning was getting more out of the facilities that we already have, through operational efficiencies that might be possible.

It is one way of conserving the very limited capital funds we have to avoid new construction.

New York was fortunate in being selected in a competitive set of proposals for what is called an integrated motorist information system [IMIS] being constructed now on Long Island, an island that has mostly heavy movements of people east-west within several corridors of travel on the island, with almost a complete inability to construct more capacity. This system is going to be a real-time system of traffic monitoring and control, changeable messages, incident management and traffic diversion, not on a single facility, but on a combination of a number of east-west facilities as well as the connecting facilities between them.

So if there is congestion on any one of them, the conditions on the alternate facilities will be known and the conditions on the interconnecting facilities will be known and the messages can redirect motorists to use those facilities where they can travel most effectively.

The benefits of these projects are substantial in saving of capital costs, savings of environmental and other disruption, tremendous savings in accident reduction and fuel consumption, air quality improvements, et cetera.

We were selected for this project as a demonstration project. The first cost was heavily funded with Federal funds. It is the operational cost of this installation, that is the test bed for potential national application, that we are expected to bear completely, 100 percent, without Federal assistance.

I think it is fair to say that there are very, very few States that would find it possible even with 100 percent Federal funding for the capital costs, to bear the cost of operating such a system, not just for the benefit of the local area, but as a national test bed.

One of our concerns is that in maintenance management, we have an inadequate data base to indicate the effectiveness, the life, the long-term costs—not just the first cost, but the total life cost—of each of the alternative potential maintenance and reconstruction strategies and choices that we may have.

The tendency, with Federal aid being available for a reconstruction, may well be to go to complete reconstruction when possible forms of maintenance may serve as adequate substitutes and be cheaper in the long term, but be ineligible for Federal aid.

What we lack is objective data both at the State level as well as on the national level to be able to show the relative effectiveness of each alternative maintenance strategy, to show which is the least cost strategy, and not just from the standpoint of what Federal funds are available for, as against what State funds would have to finance. We have created a pavement management task force to address this question.

We have developed computer simulation models to indicate what would be a better choice of maintenance strategies or reconstruction strategies on a systemwide basis and we are perfecting this model to assist in making individual project choices as well.

FHWA has identified pavement management as a research area for emphasis. We are supportive of them in that effort.

The lion's share of our capital and operating budgets are devoted to maintaining, preserving, and rehabilitating our highway pavements.

Research management is an area that I have been concerned with for a long, long time. FHWA contract research accounts for 43 percent of the research funds that FHWA reports under the federally coordinated program for highway research and development. This and FHWA staff studies make up half the total expenditures under that program and this has remained essentially the same for the last 5 years.

That is about equal to what the States are spending for research under the HPR program.

We in New York traditionally devoted a substantial portion, between 20 and 30 percent, of our HPR money for physical research, not counting soft research. In addition, since there is inadequate HPR money to cover all of the HPR eligible activities, we fund further research activities with 100 percent State funds, augmenting the HPR program.

In the FHWA contract research program, the States do not really have a role in either project identification, selection, research evaluation, or technology transfer. The States are truly the major part of the clientele for this research. Since they are going to be the beneficiaries, they can provide the benefits of client input and involvement, and commitment to the research findings, if they have a role in and involvement in that program.

I think it would result in much greater payoffs from that part of the total spent on highway research today. FHWA has created advisory councils for that research program but they specifically limit the membership on the advisory councils to FHWA personnel.

Only one member of the council is a regional representative from the FHWA. He comes the closest to possibly having a State perspective.

I would suggest that advisory panels similar to those used for the NCHRP program would prove to be advantageous.

As a point of contrast, the States, in order to use the HPR money, are required to submit to FHWA detailed and voluminous reports which outline proposed uses of the HPR funds for the forthcoming year. Since FHWA has that document for prior review and approval, FHWA has the mechanism to provide for coordination, the potential for elimination of duplication and also to foster technology transfer.

Unfortunately, that is a one-way street. The States don't have the benefit of information from the review of those submissions of the other States. Nor do we have information relative to the FHWA contract and in-house research programs.

So I believe that we can get much more return out of the dollars already being spent by a more effective coordination mechanism amongst the States and between FHWA and the States.

The transportation research board is an extremely effective mechanism to bring the States and their thinking and input together, but more can be done, I think, within the dollars spent through making more effective use of the FHWA funding.

We feel that obviously more money should be provided for transportation research and specifically highway research, but there is much more effective use that can be made of the funds already being provided.

I would like to cover a couple of points and questions mentioned earlier. One related to Portland Cement and the alleged lack of industry research and development in the area of Portland Cement. We happen to have a cement company in New York that has developed a new product, called New Cem. The Atlantic Cement Co., which is part of the Newmont Mining Corp., has developed a product using iron ore slag, in this case coming from the Sparrows Point plant in Baltimore, which will substitute for a goodly portion of the aggregate normally used in Portland Cement and even though incurring the shipping costs of that slag, Atlantic Cement feels they can be price competitive in the New York upstate market with a product that will actually be an improved product over what we have today in Portland Cement. We have a proposed demonstration installation of that product scheduled in New York soon.

The AASHTO test road was mentioned. I believe much has happened since the old AASHTO test road, as facilities have changed greatly in those years. The time has come for another test road or another real life test facility, a full-scale facility, to be considered.

There was mention made of the UMTA research programs and demonstration programs, and the relative lack of application of much of what came out of those programs. I think that again was a case of fragmemtation of effort, but without the mechanism of the transportation research board or other mechanisms to provide some capability to establish an overall framework and focus for the research to be undertaken, the demonstrations to be undertaken and the subsequent technology transfer.

Besides the much heavier trucks that the interstate system and our bridges are expected to cope with today, there was no mention made of studded tires which we in the North have to cope with. They did not exist at the beginning of the interstate program and they are the cause of an extensive amount of wear on highway surfaces sufficient to expose the reinforcement bars. There is then extensive salt corrosion when the reinforcing bars are exposed.

Through recycling materials, we are getting improved use of aggregates and other materials that the States have. In New York we early on concluded that limestone was not a product that we would use in portland cement or in asphalt cement because it is a softer material. It has characteristics that result in a poor final product. It also tends to polish when in the surface coarse so you end up with much poorer skid resistance than otherwise.

So New York only permits limestone in the base courses of asphalt concrete projects.

For bridge decks we had contracted for extensive research in improving portland cement materials to prevent salt intrusion through the concrete. Today we specify two alternate products we developed in that research, one is called a high-density concrete, the other is a latex modified cement concrete.

Both are very effective to prevent salt intrusion and, therefore, prevent bringing the salt to the level of the reinforcement steel in bridge decks.

I thank you for the opportunity to appear today, and I want to commend the two committees for identifying transportation research and particularly the highway infrastructure research and highway infrastructure needs as the subject of concern and consideration for the two committees.

Thank you.

[The prepared statement of Mr. Mladinov follows:]

PREPARED STATEMENT OF JOHN K. MLADINOV, EXECUTIVE DEPUTY COMMISSIONER, NEW YORK STATE DEPARTMENT OF TRANSPORTATION

I appreciate the opportunity to appear here today to discuss transportation infrastructure research.

In New York State the emphasis of our efforts is increasingly on the preservation of our transportation facilities network in a usable and safe condition. The State system of highways and bridges is vital to the maintenance of commercial activity throughout the State. Almost all of the goods and freight which move in and through the State must utilize State highways at least part of the way, and the majority of the State's work force must use these highways to get to work. The importance of maintaining an adequate transportation infrastructure in New York State cannot be overestimated.

As for our State highway system, until the early 1970's, the emphasis of the State's highway program was on the construction of the new highways which were needed to support our growing population and expanding industries and to take care of the backlog of needs that resulted from the depression years followed by WWII. To a great extent, the era of new construction has passed. We have completed most of the Interstate and other new highway facilities we believe necessary to our economy. Since the early 1970's we have been focusing our efforts on the reconditioning and preservation of the highway network which is already in place, and in more recent years, almost exclusively so.

Last year the NYS Department of Transportation awarded $550 million of highway contracts. Only $147 million or 27 percent, was allocated to new construction. The remaining three-quarters of the program was dedicated to preservation and improvement of our existing facilities. Five years ago, new construction accounted for 58 percent of the program. This is a situation which I am sure we share with other states in the Northeast and Midwest.

Maintenance

As we in the Northeast have moved from expansion and building new facilities to preservation of the existing system, highway and bridge maintenance take on increasing importance. Unfortunately, because of recurring fiscal crises in New York throughout the past decade, the State has not been able to provide an adequate level of funding for maintenance of our highways and bridges.

The lack of Federal funding, on which we have become increasingly dependent in an era of financial crises, undoubtedly has also constrained legislative appropriations for maintenance. Nonetheless, more than half of our Department's work force has been and continues to be devoted to highway maintenance.

Many if not most field maintenance tasks remain highly labor intensive, and are performed using methods virtually identical to those of many years ago with equipment that has increased the productivity of the more labor intensive highway maintenance activities but which has had little impact on most maintenance functions. Given the large portion of the transportation budget that is devoted to maintenance, a great deal needs to be done to improve the efficiency of maintenance operations, and to develop materials and equipment which will be longer lived and more effective, particularly under adverse weather conditions.

With this need in mind, it is of interest to note that only 1 percent of the so-called Federally Coordinated Program of highway research and development is directed toward maintenance. This program represents the Highway, Planning and Research studies of the State highway agencies, FHWA contract research studies, the NCHRP program and the FHWA staff research program.

Three times as many dollars as are spent on maintenance are spent on the management and coordination of research and development activities. This seems to clearly be an area where a change in direction and emphasis is needed. While equipment manufacturers have developed new and more versatile pieces of equipment to ease and make more productive the highway maintenance efforts of our maintenance manpower, and material manufacturers have developed some improved maintenance materials, by and large the maintenance techniques, methods and materials of today are the same as 30 and more years ago.

Improving Operational Efficiency

Improving the operational efficiency of existing facilities is another area where more research effort is required since improved efficiency of operation may obviate the need to increase facility capacity through expansion of existing facilities or construction of new ones, at high capital and potential environmental cost. Vehicular demands on many traffic facilities have already exceeded both the available and planned capacity. These heavy demands not only lead to the daily recurring congestion so familiar to comuters, but also result in erratic operation, accidents, and extreme motorist aggravation brought on by lengthy and, in some cases, unexpected delays. Traffic congestion problems also result from the presence of disabled vehicles, other distracting roadside events, construction, maintenance operations, etc.

To combat these problems in the face of the increasing social and economic pressures against construction of new highways or increased highway capacity, highway authorities have recognized the need to obtain better utilization of existing facilities, particularly in the context of real-time operations the potential payoff can be very large. Unfortunately, individual highway departments are largely unprepared to invest large amounts of money for high cost realtime developmental type projects, much less to have in house the sophisticated skills that might be necessary to design and carry out such a project successfully. In attempting to cope with these types of emerging problems involving very high volume facilities or networks, a number of projects dealing with such proposed solutions as changeable message signing and real-time motorist information systems have been initiated.

New York has begun installation of an Integrated Motorist Information System (IMIS) to relieve traffic congestion in the Northern Long Island Corridor through the use of traffic monitoring, control, incident management and traffic diversion. Construction is scheduled for completion in mid-1985. The significance of the project is that it is the first large-scale integration of the most advanced existing technology. The benefits of projects of this kind are substantial in terms of the potential for accident reduction, fuel savings, savings in commercial travel time, reduced vehicular congestion and operating cost, improved air quality, etc. to say nothing of the avoided dollar energy and environmental costs of constructing additional lanes or new facilities. In many crowded freeway corridors, construction of new facilities is not truly an option, which makes improvements in the operational efficiency of existing facilities a critical need.

Here again, funding of research projects in the traffic operations category within the Federally Coordinated Program was only $4.5 million in 1982, or 10 percent of tntal highway research and should receive more emphasis.

Pavement Management

There is a consensus that the nation's physical plant requires a massive investment for refurbishing. At the national level, estimates of the repair bill for highways and bridges range up to $100 billion. To worsen the picture, evidence from the Highway Performance Monitoring Study suggests that road conditions are the poorest at the local level, but these government units are now being called upon to bear the brunt of Federal cutbacks in many programs. Unless significant attention is paid to this prnblem soon, the United States runs the very real risk of losing the vast investment of its local highway infrastructure.

There is a critical need for managers to be aware of the related effectiveness and the consequences of decisions that they may make, and to have means available to teat alternative strategies and policies. This requires objective data to describe the current and probably future states of the transportation network and the results of each of the many availabe methods, courses of actinn and strategies to maintain, preserve and extend the life of our capital plant. With such data, economic analysis will yield the least-cost strategies for providing needed transportation facilities.

Yet, the data available to undertake this task are spotty or unavailable. Numerous procedures have been developed to evaluate alternative highway rehabilitation strategies, but often their context has been limited to the study of a handful of sections and they do not handle system level analysis. Detailed analysis methods of rehabilitation strategies for individual sections are well advanced, but the magnitude of the overall network problem goes well beyond the ability tn study definitively lack of a host of individual sections. The use of different highway rating procedures in different states has exacerbated the situation and clouded comparisons between systems. It is safe to say that the true magnitude of highway and bridge deterioration nationwide has not yet been quantified in a nniform and consistent fashion but clearly, the states and local governments need the capability to assess highway condition and determine optimum rehabilitation strategies.

Recognizing these issues, New York State has undertaken a concerted effort in the field of pavement management. A Pavement Management Task Force was formed to review present procedures and recommend improvements in pavement management. Methods for determining highway condition, and reporting it in timely fashion are being improved and streamlined. Studies to understand deterioration and methods to correct or forestall it, short of reconstruction, have also been initiated. Computer models have been developed to assist in exploring various pavement management strategies. This work is on-going and is expected to yield a better capability to manage pavement needs in a more cost effective manner than before.

I understand that pavement management has been identified by the FHWA as a research area for emphasis. We are supportive of FHWA's recognition of the importance of pavement management since the lion's share of our capital and operating budgets are devoted to maintaining, preserving and rehabilitating our highway pavements. Pavement management is of prime importance to us in our efforts to preserve and improve our existing highway network.

The FHWA Contract Research Process

I would like to now address my remarks to the research management process, specifically to research undertaken by the Federal Highway Administration. FHWA contract research accounted for 43 percent of funding for the Federally Coordinated Program for Highway Research and Development during 1982. This figure was the same or somewhat higher during each of the past five years. This means that funding of this element of the program is equal to the total HP&R program. Yet the states do nnt have a substantial role in project identification, selection, research evaluation, and technology transfer. Since the states are a major part of the clientele for this research, the benefits of client input, involvement and commitment to the research findings is lost.

Increased involvement by the states in contract research by FHWA should result in larger "payoffs" from the work. Advisory panels similar to those used for the NCHRP program might be advantageous.

While this statement is heavily oriented to the highway system, its condition and research needs, much of what has been said also applies to the other transportation modes as well. If anything, the other modes are probably far more deficient in uniform and consistent appraisals or conditions and needs, as well as needed research since they have no equivalent to the HP&R program, and only recently has there been the equivalent of the NCHRP program for the transit mode.

Mr. GLICKMAN. Thank you.

Recognizing the time limitations, I will ask you all questions. If you all want to comment, fine. If you think that you agree with your colleague who commented, you may not necessarily have to comment again.

Starting out with a question of Mr. Carney, a significant part of available transportation funding has been dedicated or diverted to public transportation. This is taken away from highway use.

Could you comment on the impact of that in your States?

Mr. MCCUE. Yes.

Mr. GLICKMAN. Mr. Pappas referred to it obliquely.

Mr. MCCUE. I can comment. That is the controversial issue, whether the dedicated funds should go to public transportation.

The logic we have used to support that diversion if you want to call it that, is that we cannot afford to add that amount of additional highway capacity, it is too expensive to buy urban land to do it. To the degree that you can use public transportation to serve the needs you are in effect saving the highway and allowing the remaining capacity to function on the highway.

So it serves a highway purpose by taking the load off the highway, or making it operate more efficiently on the highway. Whether it works is the question. We hope it will because we cannot afford to do anything else but we cannot be sure that it works.

Mr. **Glickman**. Mr. Larson.

Mr. **Larson**. It has always been remarkable to me that there is such a strong adversarial position between modes that are obviously all needed. In Pennsylvania we have major cities, Philadelphia, Pittsburgh, and a number of others, where there is absolutely no option except to have a variety of transit loads and we in the State provide $200 million a year in subsidy for those services because they are needed.

We obviously with a large rural population have to take care of those needs. So it seems to me that it is a very wasteful exercise to discuss the merits of one over the other. We need both but in a different context and the need changes over time.

Mr. **Kemp**. They are needed in different places. We don't have the same problems in Kansas, of course. I testified before a Senate committee in opposition to the idea of dedicating one cent of the motor fuel tax to transit purposes. We get back so little in Kansas on it and we don't have the same problems that they have elsewhere.

Mr. **Mladinov**. Basically New York has a very large interest in providing transit and transit services. We very heavily subsidize them today. There is about $3 million a day of subsidy going into the New York City area subway, rail, and bus systems to subsidize operating costs.

The State is very heavily involved in that. We feel that the proportion of the national transit program coming to New York is not reflective of those needs or the proportion we have of the national transit riders, but obviously we need both, we need highways and transit.

The New York environment is one that dictates a high level of transit use and high level of transit facilities. New York is a general fund State. We don't dedicate our highway user revenues to highway purposes and we feel there is no validity to arguing the point about so-called diversion of Federal highway user revenues. They really are taxpayer funds.

Mr. **Glickman**. Let me get to something that is a little more minuscule in the broad picture but after 40 years of using salt as a deicer in the winter are we still looking for a suitable noncorrosive salt substitute? It is crazy that we have not in any way modified the method for deicing roads and it happens to also be true on airplanes, we are still using the same deicing mechanism to deice airplanes as we did 30 years ago.

But we are talking about roads. Do we have alternatives?

Mr. **Mladinov**. Yes, but they are more expensive, there is calcium chloride for one which is a type of salt; the airlines are using an alcohol material basically on their aircraft. We have had tests of using an alcohol-type liquid for bridge deck deicing, which is where most of the salt damage comes. It is an expensive alternative but an extremely effective one.

More recently another chemical is being heavily researched—(calcium magnesium acetate). The major problem is that there isn't a sufficient market yet to create the production facilities to bring the cost down. In the final analysis costs will come down. While even then it may not be cost-effective on a first-cost basis compared to salt, but on a total cost basis it is going to be a preferable solution.

The research is under way and I think we are headed in the direction to eventually switch away from the salt that has been used in the past. There are a lot of environmental detriments from use of salt. We are limiting the use of it in New York. We would like to switch to a substitute, but now it is at high first cost.

Mr. GLICKMAN. Anybody else?

Mr. LARSON. Only to the point with other words to reinforce what John said. We have not in our business used life-cycle costing and in the State of Florida or in Pennsylvania where secretaries come and go with great frequency you try to make the most you can of the dollar you have and in Pennsylvania we are allegedly the largest purchaser of sale in the entire world, and the first cost of that is something that obviously has to be considered.

The winter before this past one we spent $100 million on winter maintenance, and obviously again the first cost of that enormous 800,000 tons of salt is something we have to worry about.

Mr. GLICKMAN. On a related question, and fairly mundane, I think this was discussed by the first panel but we have done cooperative Federal and State research on roads and road making for 100 years, since 1893, I believe. Why after all this time are we still doing research on potholes and pothole repair?

Mr. MCCUE. Mr. Chairman, I think one answer is the one I offered in my opening statement, that we don't take into account the use of the system. The road is designed for a certain purpose and we use it with much greater volume of traffic, greater weights, or more commonly both, and it just is not—our experience in Florida is the roads have essentially lasted for the period they were designed for. It is just that the period occurs in 5 instead of 20 years. We have much heavier traffic and higher volumes of traffic. As Mr. Larson pointed out, the environment of that road is severe. It is probably as bad as the surface of the moon when you consider the abrasions it suffers.

We don't have a material that can withstand any kind of impact continuously for a long period of time. We don't have one we can afford at this time.

Mr. LARSON. The pothole phenomenon—I am happy to announce Texas has indicated they have the most potholes.

Mr. GLICKMAN. Something else, too.

Mr. LARSON. We don't challenge them on that. If something goes wrong in a localized area, that failure is different in different places so the remedy ought to be different in different places.

So to think there is a single pothole fix that we should have discovered 50 years ago and would be applicable for all time and all places is probably extremely naive. But between a deal with the public in our business you find out that whereas they don't know anything about the things on the wall here they know everything about roads.

Just listening to the members it is obvious they know everything about the roads and bridges also. So we work in a very, very difficult environment.

Mr. GLICKMAN. I am glad we know something about something.

Mr. **Kemp**. Mr. Chairman, I would observe that I suspect the Chinese roads even with the 6-foot thickness if they carried the traffic volumes that we have would have potholes similar to what we have. I agree it is a localized area problem and it is related to the traffic volumes and axle loadings and gross loadings.

Mr. **Glickman**. You talked about a success story on bridges with the rebar insertion technique.

Mr. **Kemp**. Yes.

Mr. **Glickman**. Has that technology spread to other States? Is it unusual, was it picked up in a trade journal? Tell me how the technology transfer has been.

Mr. **Kemp**. The TRB gave it publicity in their publications and I hope other States pick it up. Certainly we want to take things they are doing and bring them to Kansas. We don't each need to invent the wheel in effect.

Mr. **Glickman**. Are any other States using this technique?

Mr. **Mladinov**. We don't have bridges of that type of construction.

Mr. **Larson**. We don't have that failure. We have other failures.

Mr. **McCue**. I am not sure whether we do but in terms of sharing information we do and I agree with John, for example, in Florida we have a $10 million a year research program. We try to share that. All the conversation has been about centralized research versus the diversified type. We probably need both but all the States spend a lot of money on research and we ought to share that information.

Mr. **Glickman**. Is there a good sharing? After all you are the people that manage all the road construction in this country, not the Federal Government. For the most part you are doing it all.

Mr. **McCue**. The main organization we have to do that is the American Association of State Highway and Transportation Officials. We have a large committee structure that is broken out by function. So we have a bridge committee within that, and those experts in each of our departments who deal with that specific issue meet several times a year and share correspondence and communication and talk about what they are doing to solve problems.

So hopefully the extent it carries over from one State to another it does.

Mr. **Larson**. One of the problems is one that I alluded to and was referred to on several occasions, that is the problem of management. A research subject doesn't always get to the top of the deck even when it has enormous implications. The operating people have budgets of perhaps $1 billion to $2 billion and a research program, even if it solves a $1 million problem might be relatively small.

So I think research has suffered because we have not had continuity of management and management that was attuned to technological advance. And the value of innovations.

Our managers are not attuned to that kind of thinking.

Mr. **Glickman**. You are talking about managers, is that State highway managers?

Mr. **Larson**. Yes.

Mr. **Glickman**. John, you had a comment?

Mr. **Kemp**. It falls in the category of we are doing some of it but we need to do a better job. In Kansas a couple years ago I appointed an engineer to do technology transfer full time. It takes somebody with a lot of expertise and know-how to pull all this together. The Federal Highway Administration has a program of technology transfer and they act somewhat like Typhoid Annie when they go around and spread things around but it needs to have more attention, a better focus.

It seems if we had that 800 number we could call if we had a problem it would be very helpful to us with somebody that is very knowledgeable about highway problems in general.

Mr. **Glickman**. Let me go back to Mr. Larson. You talked about management. When you talk about the top highway management has abdicated its management role in research, with the result that research has not often been attuned to policy or future needs, I want to be sure I know who you are talking about. Would you include Federal management as well?

Mr. **Larson**. Yes.

Mr. **Glickman**. What about management in the road building industry?

Mr. **Larson**. That is basically private sector management and they have not had as we heard discussed around here, a strong profit motive for doing things that are to great advantage. But I also want to point to success stories.

We are going to pave, repave a particular expressway in a particular way and part of our life cycle cost approach to this includes the fact that you can now mill off blacktop pavement and restore them with new pavements in a very short time frame. So that the private sector industry that developed milling capability where you grind down if you will and save the refuse is a very important technological innovation that as near as I know came from the private sector.

Certainly we are past most of the interstate now, but the economics of earth moving made possible the building of the system, the big equipment manufacturers and paving companies that built the big equipment fleets that operated at a very cost-effective fashion, we have built the system without the benefit of the kind of labor-intensiveness that China has and wants to use and very clearly be world leaders in the developing roadbuilding equipment business and we are marketing that around the world. Probably there is some Caterpillar equipment over in China right now.

Mr. **Kemp**. In connection with the private sector I think a lot of States are doing what we are, value engineering, so-called, where if a contractor has a proposal to save money to provide the same product we asked for at a lesser cost we will allow him to do so if we are satisfied it is satisfactory and share the cost savings with him.

So there is incentive for the private sector to come in through the value engineering approach and give us savings in methods or in materials.

I would guess all the States are doing some of that.

Mr. **Glickman**. Let me ask—go ahead.

Mr. **McCue**. One of the problems Mr. Deen pointed out is how do you know if it is really equal in performance. Someone comes in with a new idea saying I will substitute this for that and save money and split it with you but how do you know it will last 20 years if you haven't tested it. You need the research capability to determine that.

Mr. GLICKMAN. If you had to list your most pressing substantive areas where you believe research needs to be done on highway infrastructure problems, what would those be?

Mr. McCUE. Well, our most pressing problem today is this question that you called diversion and other people addressed of the role of the other transportation modes. We know for sure as the other States have found that we cannot carry all our traffic on the highway system. We need some good information on the degree to which we can cause people to choose freely to move off the highway system to other modes. That is the real major problem in Florida today.

The other is economical construction techniques and use of what is out there. It is easy to talk about getting exotic materials to build roads but the fact of the matter is that the common materials like limestone and cement and asphalt are there and that is what we will probably use. What we need is research into the best ways of using what we have as opposed to finding something different that might eventually be better.

Mr. GLICKMAN. Mr. Larson.

Mr. LARSON. My list would be probably similar to what you have heard. First of all we need better institutional frameworks for accomplishing and using better technology.

Second, we need to have our high-cost items researched to the point of being able to make better life-cost decisions.

Then I guess the third one that I would mention would be probably in the area of trying to improve our construction techniques both in terms of lowering cost and lowering time. We are rebuilding and the Nation is rebuilding a lot of the old initiated highway systems where they now carry enormous volumes of traffic; and that they are finding ways to rebuild the facilities while the public is using them is something we have a long way to go on.

Mr. KEMP. I would echo what they have said pretty much. I think pavement management certainly would have to come high on any list that we would have in Kansas because we spend such a big share of our total construction and investment dollar on pavement. We are developing a pavement management system but we are just kind of finding our way.

Certainly the management area is one that needs a lot of attention. How can we better use what we now have?

I think that is about all.

Mr. MLADINOV. I would endorse those. As I said in my earlier statement, such a big proportion of our total budget is directed to maintenance, there should be increased research aimed at the maintenance area, improved materials, improved techniques and methodology. That is part and parcel of the management program as well. That is what pavement management is all about, to maximize the capability and at the least cost in keeping the facilities in operation.

I would emphasize the necessity for research management so that we can get a better utilization of money already available for research and to do that within a structure and focus for research and a framework for the research.

I think the groundwork for that is underway with the study that is being funded, at this point being carried out by TRB that Tom Larson is involved in.

Mr. **Glickman**. I wonder if you can each tell me in your States, can you quantify in dollar terms the infrastructure problem? I guess by problem I would mean replacement or rehabilitation of existing structures, bridges, and roads.

How much in current market figures will it cost you?

Mr. **McCue**. There are two things to look at, and we keep hammering at the legislature, you have to look at structural integrity; second, operational integrity. Is it carrying the traffic it needs to carry?

We have both problems. We have the systems falling apart but we have systems that are relatively sound physically but they are jammed with traffic. They cannot carry it.

We are currently spending $1.5 billion a year thanks to the new Federal tax increase and our State tax increase and we think that will keep the system physically intact as it is today, in other words, it is not enough to make it any better, about a third of it is in real poor condition and it will stay that way permanently because, as we fix it, more gets worse.

So in Florida $1.5 billion keeps it intact. It doesn't begin to approach the operational problem. We have given up on that. That was the billion-dollar-a-year cost that I mentioned that we cannot even imagine dealing with. So we are trying to find another way to deal with that.

Mr. **Glickman**. Mr. Larson.

Mr. **Larson**. I think it is a disservice to try to put numbers on this figure because the number is so large as to be meaningless. When you talk about $1 trillion or $1.5 trillion, people's eyes just glaze over. I think it has to be in more specific kinds of terms and we try to talk in terms of specific bridges, specific roads, and impacts in Pennsylvania. That is a more meaningful approach.

The highway community has done itself a disservice by putting out numbers that are simply incredible or at least nondiscernible to the public.

Mr. **Glickman**. Mr. McCue, you talked about how much the State of Florida spends on an annual basis. What do you spend annually, Mr. Larson?

Mr. **Larson**. We have a $1.4 billion bridge bill that we promoted through our general assembly to fix 979 bridges. I can identify every one for our general assembly members. That is specific. This summer we are spending $154 million on interstate highway restoration and I can show every mile where it will happen.

I can go on that way.

So that kind of specificity, I think, has to happen because people vote for improvements, not for overall needs.

Mr. **Glickman**. Mr. Kemp.

Mr. **Kemp**. Our budget is about $400 million a year in Kansas and I would say, yes, we could calculate the needs and we would get you a large, large figure. As Mr. Larson indicated, we probably need to go to an investment type approach where we can say what good could we do with *x* dollars if the needs are *5x*, how much do you do with *1x* or *2x* or something like that. That is what we have had to do. We would try to preserve the system as best we could with a part of the needs.

There is no way we will get all the needs. It is too big.

Mr. **Glickman**. The State of New York?

Mr. **Mladinov**. I tend to sympathize with that position, although we have developed a number. We make everyone aware of the fact that when it comes to the local systems there is very little information that is available really in a consistent fashion for the local systems. In the State of New York, the local systems, non-State highway facilities, are in much poorer condition with a higher level of deterioration than the State facilities.

We have cited a cost of what we say is necessary over the next 10 years in order to hold our own. But recognizing that our knowledge of what the local facilities' conditions are and how they can be maintained is less than adequate, that number is $27 billion.

Mr. **Glickman**. We thank you, gentlemen, for your excellent testimony.

This concludes today's hearing. Our next hearing will be Wednesday, June 15, when we will hear testimony from the private sector on basic and applied research and development; development in Portland Cement research; and research in transportation infrastructure materials.

The hearing is adjourned.

[Whereupon, at 1:15 p.m., the subcommittee was adjourned, to reconvene on Wednesday, June 15, 1983.]

TRANSPORTATION INFRASTRUCTURE RESEARCH AND TECHNOLOGY

WEDNESDAY, JUNE 15, 1983

HOUSE OF REPRESENTATIVES, COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT, AND THE SUBCOMMITTEE ON TRANSPORTATION, AVIATION, AND MATERIALS,

Washington, D.C.

The subcommittees met in joint session, pursuant to call, at 9:35 a.m., in room 2325, Rayburn House Office Building, Hon. Dan Glickman (chairman, Subcommittee on Transportation, Aviation, and Materials) presiding.

Mr. GLICKMAN. Good morning. Today the Subcommittees on Transportation, Aviation, and Materials and Investigations and Oversight begin a second day of hearings on highway infrastructure research and technology. Last week we heard testimony on the overall problems and research needs with regard to highway infrastructure research. Today we intend to focus in on some of the research underway in the private sector, such as cement and materials research and development.

We have a number of very excellent witnesses here who have agreed to help us today. I look forward to hearing some most enlightening testimony.

Chairman Gore.

Mr. GORE. Thank you, Mr. Chairman.

Last week, at the beginning of our hearings, we heard from prominent researchers about the low levels of funding accorded to this particular field of research and, perhaps more importantly, about the fragmentation of the highway program resulting in an inability to focus on the several major research gaps. We also heard from State secretaries of transportation who stressed the major economic benefits to be derived from research conducted in the field and supported the need for a greater effort.

Today we will hear from senior private sector corporate executives with research and development responsibilities. We will also hear from top managers of major university research centers, including a guest from the University of Surrey in England, and from representatives of the highway and bridge construction and paving materials industries. We welcome their testimony on this important topic.

We will conclude this set of three hearings tomorrow when we hear from the Department of Transportation. Hopefully, at the conclusion of these hearings, we will have a better understanding of the strengths and weaknesses of the research effort and then be in a better position to insure that future expenditures on highways and bridges are both economic and effective to protect and enhance the enormous national investment in transportation infrastructure.

I fully anticipate, after talking with some of my colleagues on both sides of the aisle in these two subcommittees, that there will be specific and pointed legislative initiatives coming out of the findings of these hearings.

Mr. GLICKMAN. Thank you. And, without objection, the statement of Mr. Carney will appear in the record.

[The prepared statement of Mr. Carney follows:]

STATEMENT FOR HON. WILLIAM CARNEY
HEARING ON TRANSPORTATION INFRASTRUCTURE R&T
JUNE 15, 1983

MR. CHAIRMAN, DURING OUR FIRST DAY OF HEARINGS ON TRANSPORTATION INFRASTRUCTURE R&T, A CONSENSUS EMERGED THAT WAS DISTURBING. IT WAS ARGUED THAT THE RESEARCH BEING CONDUCTED IN THIS AREA HAS BECOME TOO FRAGMENTED AND LACKING IN DIRECTION OR FOCUS TO BE EFFECTIVE.

SOME INTERESTING QUESTIONS WERE ALSO RAISED: WHAT KIND OF TRANSPORTATION INFRASTRUCTURE WILL WE NEED IN THE NEXT GENERATION? TODAY WE SEE SMALLER CARS AND LARGER TRUCKS THAN OUR HIGHWAYS WERE DESIGNED FOR. SHOULD WE CONTINUE TO DESIGN AND BUILD TOMORROW'S HIGHWAYS FOR TODAY'S TRAFFIC NEEDS?

WE ALSO HEARD SOME DISCOURAGING COMMENTS ON INCENTIVES FOR PRIVATE SECTOR RESEARCH. CLEARLY, WE NEED TO LOOK AT THE PROCUREMENT SYSTEM CURRENTLY USED WHICH REWARDS THE LOW BIDDER AND DISCOURAGES NEW TECHNOLOGY AND INNOVATION.

TODAY'S WITNESSES SHOULD HAVE SOME INTERESTING INSIGHTS INTO THESE PROBLEMS THAT SHOULD AID THIS COMMITTEE IN ITS EFFORTS TO ENSURE THAT TAXPAYER DOLLARS BEING SPENT ON TRANSPORTATION RESEARCH ARE NOT BEING WASTED.

I LOOK FORWARD TO HEARING THEIR VIEWS. THANK YOU.

Mr. **Glickman**. Congresswoman Schneider, do you have any remarks?

Mrs. **Schneider**. No, Mr. Chairman.

Mr. **Glickman**. OK.

It is a pleasure to welcome our first panel, a panel on private sector and basic and applied research and development. Dr. Ralph Gomory and Dr. Randall Erickson. Why don't you both come on up here.

I might mention to you both the fact that we will go into session at 10 o'clock, so it means we may be interrupted several times during the day with rollcall votes. I wanted to alert you to that fact in advance.

Second of all, I would encourage you to do the best you can to try to keep your prepared statement to the minimum that you can—because your entire statement will appear in the record—so we will have plenty of time to ask questions.

So, Dr. Gomory, why don't you go ahead and proceed.

STATEMENTS OF RALPH E. GOMORY, PH. D., VICE PRESIDENT AND DIRECTOR OF RESEARCH, IBM CORP.; AND RANDALL L. ERICKSON, PH. D., PROGRAM MANAGER, 3M CO.

Dr. **Gomory**. My name is Ralph Gomory. I am a vice president of IBM and since the last 12 years have been the director of research. I certainly feel honored to be here and have a chance to talk to you about research and technology.

Sometimes I find, when I talk about it, I'm almost embarrassed, because the things I have learned in the last 12 years always come out sounding so simple. I am consoled, though, by the fact that the simple things it has taken me to learn are not always commonly known, because the R&D process is not one that gets written about very much and it doesn't show up on college campuses and courses.

I am really going to talk about two things. One is the power of technology and the other is the R&D process itself. I, myself, am very much impressed by the power of technology to do things and to make progress, not only in the areas that we customarily think of as high technology, but in almost every area in which it is tried. I think it is commonly accepted, and I think we only have to look around the room here to see the sort of world in which it is assumed that progress can be made, these pictures of space and so forth.

However, it has also been my experience that with the proper organization and effort very substantial progress can be made in the areas that are not thought of as high technologies. So I kind of reject the notion that R&D is only for high technology. I don't honestly believe that. I'm going to give you a couple of examples.

Of course, I come from the computer industry, and people tend to identify that with electronics and chips and other very high technology items. However, if you ever actually look inside a computer, you will find a lot of metal with a few chips lying around. A lot of that is a thing called "the board," and I can only tell you the board is a very messy, heavy object which is made by standard manufacturing techniques, like electroplating and so forth. Yet it has been over and over again our experience that if you can get people who are skilled in science and technology to deal with the set of problems which the board represents, very rapid and steady, though evolutionary, progress results. Every year all the wires in the board have less and less defects in them and it becomes possible to make them both smaller and cheaper, and it becomes possible to test them better so there are less failures in the field. That steady evolutionary progress is, in spite of the more spectacular things we read about, very much the backbone of progress in computers.

Similarly, when you think of computers, you again think of chips, but when you pay for computers, you notice you pay for the printer. The printer is as sturdy an old-fashioned piece of technology as you really want to ask for. It really consists of banging a piece of metal up against a ribbon and driving ink into the paper. There is nothing more straightforward and grubby in the way of technology than that kind of mechanical device.

Yet again we find, in what you would not consider high technology, by studying the materials very carefully and building better materials every year, that we can hit the hammers harder and that they can go for millions and millions more strokes before they develop cracks, that by modeling, and modeling with great sophistication, the impact of the hammer against the paper, the way it rebounds, the way it vibrates—it has to stop vibrating and get back in position before you can hit it again—that we can redesign the hammers and therefore, because of this rather straightforward low technology work, we can make the printers print faster and cheaper every year.

So the point I am trying to make in this first part is that the power of technology is there and it is not there only in the things that one generally thinks of as high technology or glamorous. So I am very much a believer in the power of technology.

Why, then, don't we see some sort of uniform progress across the board? I think that comes to the second part which relates to the organization of research and development, so that basically all I have said up to now is that the potential is there. Now the question is how can you make it work for you.

I am going to describe the steps of the R&D process, and for this purpose I have divided it up into three parts. The first is deciding what to do; second is doing it; and the third is technology transfer or transferring the accomplished project into practice—and that third part is very difficult.

First of all, when you think about deciding what to do—which is the first part of these three things—you may automatically think of looking at a menu of choices, and at a certain point maybe you do. However, by the time you look at a menu, it is quite late in the process because the menu may turn out to suffer from certain very common and basic flaws, depending on the group that you're working with. I will just name some of these.

One I call the flaw of the dream world, which is that the things that the research and development group likes and wants to work on are very, very removed from the real world. In computers it often means that, instead of working on printing, they would rather work on electronic mail; that is, everything is electronic and is sent around, because everybody has a terminal, so why bother with this grubby business of printing. It is very alluring, but it has nothing to do with reality.

That is a very common flaw, because the lists are drawn up by technical people and they love to do what they love to do. It is very important to avoid these flaws by having, even far back in the R&D process—and "back" meaning a long way from the product and near the beginning—people who really understand the use of what you want to do.

There is a second flaw in the choosing process that is similar, which is not knowing in enough detail—and sometimes the detail has to be very detailed and very grubby—what it is you are trying to do. For example, in printing, it is again very alluring to try and get away from this very grubby business of the hammer driving into the paper and, instead, let's just fire the ink through the air, which you can do with a little nozzle, and you can direct the ink by various means, get a charge on it and divert it so that it paints out the letters. This is a very attractive form of printing that really exists, and it's called "ink jet."

However, you have to realize that there's a world out there that makes multipart forms, carbons. Many businesses have embedded in them four-part, five-part, six-part, and seven-part forms. Let me tell you, a quick splash of the ink on the paper does nothing for all those forms. You have to know that sort of thing in order to know that your ink-jet printer is going to have to run faster than the impact printer because it is going to have to serially produce all these forms. I addition, for businesses to accept it, they will have to make changes, many of which they won't want to make. That kind of detailed knowledge is absolutely essential to a realistic assessment of what you're going to do. So the main point there is, even in the choosing and making the list of choices, you do need very detailed knowledge of the end result.

Now, a second aspect of choosing is, is it or is it not technically feasible, and if you're a manager of this sort of thing, you may not have the technical knowledge to assess that, and if you're in doubt, and if you have doubts about your people, then you should bring in outsiders.

But another aspect which generally gets neglected is to ask the technical people what will it do for me if it's technically successful, and to listen carefully to the answer. Because what you tend to hear back is "it will have tremendous impact; it is technically very exciting"—only they don't quite use those words. In other words, if you're dealing with technical people, they are turned on by technical things. They know about that and they know less about the ultimate use.

So again, I think you have to be very critical about the question of ultimate use, and you must ask your people to explain in detail what the impact will be, because they will be enchanted with the technical aspect of it, which is vital, but don't forget the other part. So much for the choosing part.

Now, the next part is doing it. When you come to doing it, there are certain obvious prerequisites for getting technical work done. The first is people—and just for emphasis, I will say the second is people. In people I subsume the notion of their skills. You can't do materials work without materials expertise. And good people make an enormous difference. That, I think, is all very obvious. After people you come to equipment, to stability and persistence of the organization and things like that, all of which are fairly straightforward.

There is one thing that occasionally is less obvious, and that is the matter of scale, scale of effort. There are too many things which do require a nontrivial scale of effort to get done, and that is because there is a lot to get done. Let me give you a concrete example rather than abstract words.

One of the things that makes up the computer system is a disk. It's a round thing and spins very much like a record, only what is recorded on it is data and not music. To improve a disk, one of the things you do is make new coatings for them in which the bits are recorded. It just doesn't do any good to invent a new magnetic coating, just like that. Of course, that's a lot of work in itself, but along with it there has to be a new material called the binder.

You then have to investigate the effect of an overcoat to protect it from the air. You then have to look into questions of corrosion. You then have to look into questions of wear, because the head that reads the bits wears on this surface. You then have to look into the substrate, the thing that holds it up, and its bumps, and whether there is a chemical interaction between the material and the substrate, for example.

Now, if you are not going to do all of these things, all of these things, it is really a waste of time, because you won't have anyone who can accept it. At that point it means an effort of a certain scale.

One thing that I notice that does tend to very often get overlooked is the necessity for having an effort of adequate size when you are dealing with things of any complexity, so that in the end there is a complete object. If you're not willing to pay the price to look at all the aspects of the object, then you really will almost certainly end up throwing your money away. So, as far as doing it, there are the skills, the people, the organizational stability, but there is the matter of scale.

Now we come to the final phase, which I often think is the most difficult of all, which is transferring the technology, which we now assume you have chosen well for its impact and you have gotten together the necessary skills and persistence and scale to bring it off. Now you want someone to use it.

An awful lot of things go right off the rails at this point. A plan to transfer the technology into practice really should have been part of your plan from the very beginning, because if you go to the user now, you will find very little acceptance if he isn't expecting it. He won't exactly tell you "It's not mine," but you will find that very little happens and that it will be almost impossible to harness his energy to the program.

You will find, for example, that his budget is committed for the next year and the year after that, and that all his people are busy. So it is necessary to get him involved very early in the process, so that he is looking at it coming and saying:

> This is going to be here the year after next; I've got some of my people working on it; I feel it is mine; I'm going to plan for it in my budget and I'm going to tell my management that it is coming; I'm going to start counting on it.

In that way, you can transfer technology. But I'll tell you, if you appear over the horizon waving the solution, nothing is going to happen.

So let me just summarize. There are three parts. There is the designing, there is doing the work, and there is the technology transfer. The common thread that runs through these is that I think you need experience and contact with the user throughout.

There are other organizational aspects and I can't summarize them in a very brief time. However, to go back to the very beginning, I think if you do that right, you can harness the enormous power of technology, not only to the things that are traditionally thought of as high technology, but to almost everything else as well.

Thank you very much.

[The prepared statement of Dr. Gomory follows:]

SUBCOMMITTEE ON INVESTIGATONS AND OVERSIGHT
AND
SUBCOMMITTEE AND TRANSPORTATION, AVIATION, AND MATERIALS

June 15, 1983

Testimony by

Ralph E. Gomory
Vice President and Director of Research
IBM Corporation

I feel honored to be here and to have a chance to talk to you about research and technology, subjects that I have certainly devoted a great deal of time to. I am sometimes embarrassed when I think about what I have learned, because it always comes out so simple. I can only tell you that these simple things that I am about to tell you about were all learned slowly and painfully.

I, myself, am very much impressed by the power of technology to do things, not only in the areas that we customarily think of as high technology, like semiconductor chips, but also in other areas that are usually regarded as much more recalcitrant. However, I am almost equally impressed by the difficulty of the R&D process, the process by which the potential of technology sometimes is and sometimes is not translated into actual products or actual improvements in areas such as transportation. I will talk about both the potential power and the difficulties today, but I want to stress the difficulties. These difficulties are more the human and organizational ones and not so much the technical ones.

I think the power is there on the technology side. This is perhaps more obvious in the extreme high-technology areas. Everyone is used to the idea that somehow tremendous progress can be made in logic and memory in computers and things like that. Microfabrication, making circuits exceedingly small, every year smaller, every year faster, every year cheaper, results in a very direct and simple way in smaller, faster, cheaper, better computers. That is true and it is obvious. What is less obvious, and what I have seen over and over again is that the power of thought - the power of technology - when applied to what appears to be more archaic and more difficult subjects also yields substantial progress. I do not think we should doubt that that potential is there. Let me give you a couple of examples. When you think of computers, you tend to think semiconductor chips. But actually look at a computer, and you do not see just a chip lying there. You see a big heap of metal. If you open it up and look inside, there are all kinds of very gross things. All these things have to be made. One very important part of a computer is the so called "board". The "board" is not a very subtle thing to make. If you have ever seen them being made, the process is basically quite crude. It involves all kinds of electroplating baths in large grubby-looking tanks. The things reside in these tanks for a while, and then they come out and then they move on to the next stage. It is very much a factory looking place.

Nevertheless, let me tell you that when you get people who understand something about electroplating, who understand all the relevant technologies, into these places and into direct contact with the people who work there, you can improve the process. What does improve the process mean? Well, it just means that when you are through with all the plating, there are fewer gaps, fewer pin holes, in what you have plated. When you put the board together, it has less of a tendency to open up and have open circuits and so forth.

Another relevant aspect of low technology is testing it afterward. Now testing is not always subtle either. Testing a board means that you select two different points in the circuit and run a current through and see if it goes through or whether there was an "open" or possibly a "short". This is not a very sophisticated procedure. Yet, this procedure, too, can be enormously improved. Using more and more sensitive instrumentation it becomes possible to detect not only "opens" or gaps, but also potential opens or gaps, in other words, perhaps a slight narrowing of the line which indicates a weakness.

Another nonobvious area is impact printing. Probably when you think of printing you usually mean impact printing, like that done by a typewriter. Impact printing is when you get ink on some piece of metal or have the metal strike a ribbon and drive the ink into the paper. Actually, look at that technology - it is a very crude technology. You usually find that there is somewhere in the mechanism the hammer, the hammer strikes a rod - depending on what the details are - a piece of mechanism that flies forward and it drives the ink into the page then it bounces back. It recovers from that and hits it again - very crude, very much a mechanical thing. Impact printing, nevertheless, in spite of the competition from the other exotic technologies, continues to improve. It continues to improve because you get in there and you analyze in great detail the flight of the hammer, the vibration of the head. When does it lose its energy? How does it rebound? How can it recover quickly so it can strike again and fall into place accurately? A deeper understanding of this crude mechanism results in progress. I only mention this to you because some people seem to think, "well, there's area 'A' you can make progress, there's area 'B' you can't". I do not believe this - I am sure there are recalcitrant areas, but by and large, my experience has been that when you tackle an area - not always, but almost always, - the technical potential of progress there is by no means confined to what is considered to be high technology.

So much for the potential. Why is it that so often the potential is not translated into practice. And very often it is not - it simply does not happen. I want to try and analyze that under three main parts of the process of translation of technology into practice. I will speak of these parts as if they were separate at the beginning. Actually, however, they overlap each other and they even feed back on each other, so it is not a simple sequence. But just for reasons of organization, to be able to speak a little more coherently, I will refer to three parts of the process. The first is deciding what to do in the way of a technological project. The second is doing it. The third is technology transfer - transferring the results into practice.

First of all, when you think about deciding what to work on, you tend to think a little bit that there is a menu - that there is a list of possible projects which you can work on. Of course, in real life you are constrained by the skills that you have - the sort of people you have and many other constraints, but even so the concept of the menu misses a great deal. It misses things because before the menu came into existence, there was an earlier phase during which somebody chose what to put on the menu. Why are you choosing among the set of choices you are choosing among? If you choose among 43 terrible choices, it does not really matter too much what you choose. Now that predecision stage is really very vital because much of the deciding is done there, and the most characteristic errors occur there. There are many characteristic errors, and by the way, they are best obviated by having people dealing with these projects who have actually had experience with the end user in the world in which it is used - in this case, transportation, in my case in computers. Characteristic errors of this stage - the first is one I call "dream world". In computers, the dream world is the world of everything electronic - it is the world in which one says "gee, we really don't need to work on printers because everyone is going to have a terminal, everyone is going to have a display, and we're going to store them away in files, electronic files, and so why do we have to mess around with this ugly, hard to handle, hard to store print - it's just going to go away, so why don't we work on the electronic world". This is very appealing to people who do not know better. Perhaps in the extreme form in that I have given it to you, it is too obviously wrong. I can only tell you that in its more subtle forms it's a common error - you may even be able to recognize analogous things that have occurred in the past in the field of transportation.

The second common error is not knowing the details of the thing that you are going to do well enough. "Enough" is hard to measure, but let me give you a gross example. Earlier I mentioned impact printing, the kind you often see, although there are many other kinds of printing, also, such as xerographic printing, or ink jet printing, where ink drops fly through the air and hit the paper. All of these have enormous appeal. It is very tempting to work on these new technologies - they don't have the noise, the clatter, or the bang of the old fashioned impact technology. It makes super sense to say, "well, instead of accelerating a piece of metal and driving the ink into the paper, I am going to fire the ink in a little stream through the air and position it. There are many ways to position it, so that it forms letters, and these nonimpact technologies are inherently better". But, one thing that you have to remember is that there is a big world out there of multi-part forms. I hate to be so grubby, but there are a lot of businesses that have deeply ingrained multi-part forms into their running. I assure you that the capability to hammer out carbons is really important - it is not all important, but it is a major consideration. And if you do not know that, your printer which is faster than the impact printer, for the same price, is really a loser because it will not make carbons - you haven't learned nearly enough about what you're doing. I am giving you a crude example, but this kind of lack of knowledge can affect your selection. This is one of the very, very common errors that happen, and you do not find out about it until much, much later. This error can occur in forms that are much more subtle than the one I have given you. Not knowing what matters in enough detail is one of the characteristic errors, and that is why it's very important to have in your R&D or technology effort people who have been with the user and know about these things.

Now we come to the process of choosing from some possible list of projects. This choosing process sometimes confuses people, especially non-technical people, partly because it is really a two part process. The first part is determining whether it is technically possible to do the project. This is hard for you to judge if you are a non-technical manager, and this is not your technical field. You can hope and pray your people are good. Or, if you are doubtful about that, you can get outsiders in to see whether they are likely to succeed in this project. This first part should not be confused with the second part. The second part is this. Supposing the project is a winner - supposing it works, what will it to for me? What will the result be; how important will the result be? It is rather important to separate these two. Very often, at least in my experience, the people who are presenting a project roll these two things up into one, into one great scramble. And when you ask, "well, what will it do for me", they'll respond by saying how great the technical achievement will be. It is very important to separate these things. It is very important not to have a project unless you have a pretty clear appreciation of why it is important and have expressed that importance in common sense terms - in terms of the end result, not in terms of the technical means of how you get there.

Now, on whom should the burden of proof rest at this phase? I strongly believe that the burden of proof has to rest with the technical team to show that its proposed project is important. Not everyone would agree with this, but I strongly recommend it as a discipline, to make them think about why it matters. If they cannot convince you that it is not only technically exciting but important, say that it is their job to convince you of that. This is another very characteristic thing because technical people (I can certainly sympathize with this, having spent my life of that side) find it very exciting to do exciting things, and there is a natural human tendency to ignore the rest. That is, they tend to ignore the non-technical part about which they know the least, namely the impact in that complex world out there. They just say, "well that's bound to happen, this damn thing is so exciting, it's going to have an impact". A researcher will go to his manager and tell him about this great thing he is going to do. The researcher says it is going to have a great impact, and the manager is impressed by the enthusiasm and technical knowledge. In this case, the manager might go ahead but no one has really seen whether there is going to be a great impact, and this question of ultimate usefulness never gets sorted out from the technical question. It is very, very important to sort these two questions out.

Now for the second phase - doing the work. There are certain obvious prerequisites for getting technical work done. One is people, second, I guess, is people again and then you come to equipment, stability of the organization, and things like that. All of these are clear, and well understood. But one thing that occasionally tends to get a little more obscure is the matter of scale. There are an awful lot of applied projects that you cannot do unless you have a certain scale of activity. Don't kid yourself. There is no point in doing it half-way. This is just a great waste of resources. For example, an important part of computers are disks, where the information is stored. Now if you are trying to introduce a new surface in a disk, a new material on which you are going to store the information, this is going to take a certain number of people. You can work on the material or you can work on its molecular structure, but that is not enough. You have to have a method of coating it on the disk; you have to have a method of coating it on the disk with very controllable thickness. You have to be able to understand its resistance or lack of resistance to corrosion. You have to understand its wear characteristics because of the "head" that sometimes flies over it and sometimes rests on it. And, if you do not do all of these things, you will never transfer the technology to the recipient because it has to all be there to work. Having half of it is just a waste of resources. So aside from doing the work, there are considerations of scale and it is often tempting to do something else. I think that in a very diffused industry like transportation , this difficulty of scale would be one that you encounter.

And now we come to the third phase, which is one of the most difficult parts of all - transferring the technology. In other words, we had a good list of things, we decided to do something - it was important, it was a technical success. Now we want something to happen. An awful lot of things go right off the rails at this point. A plan to transfer the technology into practice really needs to be part of your plan from the outset because this is an awfully difficult process. The barriers to it are human, often due to the famous "not invented here" factor. In other words, you bring it to someone and he says "it's not mine". He doesn't say that directly, but somehow nothing happens. You find you cannot harness his energy to the project. Second, you suddenly appear over the horizon with all the solutions to a person's problems and he is not ready for it. His budget is committed for next year and the year after that everyone is still tied up. "Yes, that sure looks like a winner, but there is no way we can work on it". I could go on, but do not underestimate the difficulty of this technology transfer process.

One of the best ways to obviate it is somewhat related to what I said earlier about experience. It is called joint projects - get the potential recipient involved as near to the beginning as you can. Get him or his people to feel it is their project. Have them do actual work on it. They develop a sense of ownership. They know when it is going to be ready, and one day it moves and they are expecting it; it is theirs. They are telling their managers and their people about it - that it's going to be here next year, and gee isn't it too bad it's a little late, and we're working hard to move it ahead, and finally comes, and it is welcome, and it is theirs. This is a very, very important thing. It is disgusting how details matter in this thing, too.

Let me illustrate this by a specific program from a long time ago. It was a mundane, applied program. It had to do with cutting wood for furniture in such a way as to maximize the amount of furniture and minimize the amount of wood that got thrown out. And to do this, we did a computer calculation, which was the chief point as far as we were concerned, about how to do this. We had an electric eye which had to function because it had to spot knot holes. Well, I had a terrible time getting anyone interested in this because it was too long ago - computers were strange things - you did not find them in furniture factories in North Carolina. But, my collaborator and I did string it together. At one point, we had an arrangement where it was going to be tried and shown to an interested party. It got up and it ran. It ran, and it cut beautifully, and it was saving wood, but two days later it was out of there. The electric eye was always clogged by saw dust.

It is hard perhaps for you to believe this device never found its way back in that factory, but it was a black eye for the people who tried to do it. They never wanted to put it back; I never found another place to try it. Details in this business matter. Technology transfer is hard. Human characteristics matter.

There are certain threads that run through the three parts that I have mentioned to you - the decision process, getting the work done, and technology transfer. One is getting people involved - get people involved all up and down the line as early as you can. Know the end user, get the end user involved. A second thing that I have not had time to develop, and I am not going to, I will just tell you that it is there, is the element of timing. Your thing has to be ready at the right time. It is as common a mistake to be too soon - too far ahead, too early - as it is to be too far behind, too late. It just is not as publicized. So your sense of timing, getting it ready at the right time, has to be right. You cannot be effective in research by being too early. That will not work either. I am not going to enlarge on that, I will just say it and clear my conscience.

So let me summarize. The power of technology is there - it is there through scientific analysis, and understanding of materials. All of these things work. They make progress possible and make it in a much wider range of areas than most people would imagine. The potential is there, but making it happen is not a thing that happens of itself. It requires a lot of thought, a lot of attention to organization, to the human factors, and to many non-technical issues. If that is done right, the effect of technology can be very impressive indeed.

Thank you very much.

Mr. GLICKMAN. Thank you very much for an excellent statement. Dr. Erickson.

Dr. ERICKSON. Thank you, Mr. Chairman, members of the committee. My name is Randall Erickson and I am a program manager at 3M Co.

My suggestions today are based primarily upon my experience in research and development at 3M, and more specifically and more recently in traffic control materials. Those are the reflective sheetings that are used extensively in traffic signing throughout our Nation's highways.

The primary emphasis of my presentation today is ways in which we at 3M have found to improve the productivity of our research and development efforts. Specifically, I will be talking about the use of strategic planning in setting those directions, those visions that we need in order to focus our research and development efforts. Second, how do we then allocate the technical resources toward those strategic directions. Third, I would like to make a couple of suggestions on how I think we might be able to increase the amount of private industry investment in transportation research, and last, I would like to describe just briefly a method that we at 3M are finding increasingly useful in improving the productivity of our operational development efforts.

I believe that our country in general, and our Nation's industry specifically, has been justifiably criticized recently for a short-term perspective on research and development. The decade of the seventies really was an immature decade with respect to direction of research and development. As one result of that, I believe foreign competition today is taking jobs away from Americans and that, maybe more importantly, the strengths of America are being questioned. One such strength is the ability of our technical resources to solve the major national problems such as the transportation infrastructure problem we are discussing today.

I think one reason for that lack of research and development, and foreign competition taking jobs away from America, is because we really haven't thought about where we want our systems to be—in this case, our transportation system. We talk about wanting the highways to be more durable, and we also want them maintenance free, and yet, really that vision has not been provided. In any kind of research and development activity we find that, if that vision, that strategic direction, is not given, that you then don't get the kind of research and development activities and you don't get the focus on the problems that are important to you. So that is the first area that I think needs to be done on transportation, that vision, and where we want the system to be, needs to be given to the research and development community.

Once that vision has been created, then we can take our resources, our people and our money, and apply those to the particular problems and desires we wish to have solved.

I agree completely with the first speaker, that research and development takes a fantastically long-term commitment. We aren't going to solve the problems that exist on our transportation system with short-term approaches. That is not to say we shouldn't have some short-term development-type activities, but we also need the applied research and basic research efforts.

Highways are expected to last at least 20 years, and that means we need that kind of timeframe in our perspective for solving that type of problem. Because, really, we won't know until those 20 years are up whether that durability problem, for example, is solved. So make the commitment and stick with that commitment because that way you can then expect to get the problem solved.

The third subject I would like to discuss is two ways that I believe can improve the private sector investment in research and development. The first method is again strategic planning. If the public sector defines where they wish the highway systems to be, then the private sector will have greater confidence in putting their investments into those directions. So again we get back to the first issue, strategic planning. Setting the direction will give, I believe, private industry greater confidence.

Second, I believe we need to relook and rethink how we purchase materials that are used on our Nation's highways. In general, our specifications are based on minimum performance standards and low bid. What you end up with in that type of situation, then, if the supplier is most efficient, is the lowest quality material that meets that specific objective or that specific specification. The thought is, how can we create some value-added concepts into those purchasing decisions. I don't have any answers on how to do that, but I think that type of concept is one that should be looked at. That is to say, if a supplier creates something that has greater value, then why shouldn't that supplier be rewarded for that higher value rather than the minimum-bid concept.

The last area I would like to discuss is the increased use of statistical techniques in improving the operational productivity of research and development efforts. This technique is called data analysis—or at least at 3M we call it data analysis—and it involves the use of statistics in a number of technical areas. The methodology of data analysis is not new and, in fact, has been applied extensively in the fields of sociology and agriculture. In fact, it might well be that this is one of the major reasons for the preeminence of our U.S. agricultural technology, that is, because they have applied statistics to their technology.

Statistical techniques would appear to have excellent application to research and development on the highway systems. The construction of highways and bridges are extremely complex processes, with a large number of variables in raw materials, processes, and environments that are impacting on the different performance factors on those highways.

I believe through the proper use of designed experiments that we can identify the particular variables that are important, we can quantify their importance, and we can use those quantifications to make decisions. In fact, if we knew the variables that affected the particular performance factors that were of strategic interest, we could then also focus our research activities toward improving those particular parameters.

In summary, what I have attempted to do this morning is to describe four ways that we at 3M have found that can improve the productivity of our research and development efforts. First of all, provide the scientists with the proper focus, the proper vision, and where you want their efforts to be; second, allocate those resources properly among basic, applied and development efforts; third, create some incentive—for example, value-added purchasing; and fourth, increase the use of statistics, particularly data analysis, in the design of the experiments that are done on the transportation system.

Thank you very much for your attention.

[The prepared statement of Dr. Erickson follows:]

STATEMENT OF
RANDALL L. ERICKSON, PH.D.
PROGRAM MANAGER
3M COMPANY

SUBMITTED TO THE
SUBCOMMITTEES ON
INVESTIGATIONS AND OVERSIGHT
AND
TRANSPORTATION, AVIATION AND MATERIALS
OF THE
COMMITTEE ON SCIENCE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

JUNE 15, 1983

MR. CHAIRMEN, IT IS MY PLEASURE TO SUBMIT TO YOU AND YOUR COMMITTEE COMMENTS AND SUPPORTING INFORMATION REGARDING RESEARCH AND DEVELOPMENT DIRECTION ON HIGHWAY SYSTEMS AND TRANSPORTATION INFRASTRUCTURES. THESE COMMENTS ARE BASED ON MY EXPERIENCES IN ALL PHASES OF INDUSTRIAL R&D AND MORE SPECIFICALLY R&D ON TRAFFIC CONTROL AND TRAFFIC SAFETY MATERIALS AT 3M COMPANY. THEY ARE ALSO PARTIALLY BASED ON MY PUBLIC RESPONSIBILITY AS "ROAD COMMISSIONER" FOR A SUBURBAN COMMUNITY, NORTH OAKS, MINNESOTA. I HAVE A PH.D. IN PHYSICAL CHEMISTRY AND HAVE MANAGED R&D FOR 15 YEARS.

THE PRIMARY EMPHASIS OF MY PRESENTATION TODAY IS THE STRUCTURING OF RESEARCH AND DEVELOPMENT IN ORDER TO IMPROVE THE VALUE OF OUR INVESTMENT IN R&D. UNSTRUCTURED RESEARCH GIVES UNSTRUCTURED RESULTS; STRUCTURING OUR RESEARCH AND DEVELOPMENT DIRECTION DOES NOT ASSURE SUCCESS FROM THAT INVESTMENT, BUT IT DOES HELP ASSURE WE ARE WORKING ON THE MAJOR PROBLEM AREAS AND THAT SUCCESSFUL R&D RESULTS WILL HAVE MAXIMUM IMPACT TOWARD SOLVING THESE MAJOR PROBLEMS AND WILL BE USED BY OUR TRAFFIC AND TRANSPORTATION ENGINEERS. SPECIFICALLY, I WILL BE DESCRIBING (1) EXPECTATIONS FROM VARIOUS EFFORTS IN BASIC RESEARCH, APPLIED RESEARCH, AND PRODUCT DEVELOPMENT (2) USE OF STRATEGIC PLANNING TO ASSURE PROPER FOCUS OF R&D RESOURCES, (3) METHODS TO ENCOURAGE GREATER PRIVATE INVESTMENT IN TRANSPORTATION R&D AND (4) USE OF STATISTICAL TECHNIQUES TO IMPROVE THE COST EFFECTIVENESS AND VALUE OF R&D.

RESEARCH AND DEVELOPMENT IS AN INVESTMENT IN THE FUTURE. AS YOUR OWN PERSONAL FINANCIAL INVESTMENTS SHOULD BE BALANCED TO FIT YOUR SPECIFIC NEEDS, SO SHOULD TRANSPORTATION R&D BE BALANCED TO FIT THE PERCEIVED FUTURE NEEDS OF OUR TRANSPORTATION SYSTEM. UNDERSTANDING THE INHERENT RISKS AND BENEFITS OF VARIOUS R&D STRATEGIES CAN HELP IMPROVE OUR RETURN ON THAT INVESTMENT. FURTHER RECOGNIZING THE FUTURE PERSPECTIVE OF R&D MEANS TODAY'S PROBLEM CAN ONLY BE SOLVED BY YESTERDAY'S RESEARCH; TOMORROW'S

PROBLEMS CAN ONLY BE SOLVED BY TODAY'S RESEARCH. BECAUSE OF THE LOW ($40-50 MILLION) INVESTMENT TODAY IN HIGHWAY RESEARCH, WE MUST BE ASSUMING YESTERDAY'S RESEARCH WILL ALSO SOLVE MOST OF TOMORROW'S PROBLEMS. FAILURE TO INVEST IN RESEARCH ON THE FUTURE OF OUR HIGHWAY TRANSPORTATION SYSTEM MEANS WE WILL CONTINUE TO PAY FOR THAT LACK OF INVESTMENT IN (1) ROADS THAT FAIL TO MEET THE REQUIREMENT OF EFFICIENT MOVEMENT OF GOODS AND PEOPLE, (2) ROADS AND BRIDGES THAT FAIL AND NEED REPLACEMENT SOONER THAN ANTICIPATED, AND (3) THE MASSIVE SOCIAL COSTS OF 2 MILLION INJURIES, 50,000 HIGHWAY DEATHS, TOTALING AN ESTIMATED $40 BILLION EACH YEAR DUE TO TRAFFIC ACCIDENTS.[1] THE RIGHT DIRECTION AND TYPES OF RESEARCH AND DEVELOPMENT ARE NEEDED TO HELP SOLVE THESE PROBLEMS.

RESEARCH CAN BE EITHER BASIC OR APPLIED. BASIC RESEARCH HAS AS ITS SINGLE OBJECTIVE THE ADVANCEMENT OF SCIENTIFIC KNOWLEDGE. IT HAS NO SPECIFIC COMMERICAL OBJECTIVE. AN EXAMPLE OF BASIC RESEARCH WOULD BE UNDERSTANDING THE REACTION OF SODIUM CHLORIDE WITH IRON. BASIC RESEARCH IS RELATIVELY INEXPENSIVE, CAN HAVE EXTREMELY HIGH BENEFITS, IF THE RESEARCH CREATES THE MAJOR BREAKTHROUGHS, BUT HAS A LOW PROBABILITY OF ULTIMATE APPLICATION TO PROBLEMS OF INTEREST.

APPLIED RESEARCH IS ALSO THE DISCOVERY OF NEW SCIENTIFIC KNOWLEDGE, BUT IS MORE DIRECTED SINCE IT HAS SPECIFIC COMMERCIAL OBJECTIVES. AN EXAMPLE WOULD BE RESEARCH ON CORROSION INHIBITION OF STEEL. APPLIED RESEARCH IS ALSO RELATIVELY INEXPENSIVE, HAS LOWER FINANCIAL BENEFITS THAN BASIC RESEARCH, BUT HAS A HIGHER PROBABILITY OF ULTIMATE SUCCESS AND APPLICATION TO SOLVING SPECIFIC TRANSPORTATION PROBLEMS.

PRODUCT DEVELOPMENT IS PROBABLY THE MOST INTENSIVE TECHNICAL ACTIVITY FOUND IN INDUSTRY AND IS THE APPLICATION AND EVALUATION OF RESEARCH FINDINGS OR OTHER SCIENTIFIC KNOWLEDGE INTO PRODUCTS OR PROCESSES. DEVELOPMENT IS

EXPENSIVE, BUT CRUCIAL IF YOU ARE TO RECEIVE ANY VALUE FROM YOUR RESEARCH ACTIVITIES. AN EXAMPLE OF DEVELOPMENT WOULD BE THE APPLICATION AND EVALUATION OF VARIOUS POLYMERS ON STEEL AS CORROSION PROTECTIVE COATINGS. IT WOULD ALSO BE THE DEVELOPMENT OF PROCESSES TO PRODUCE AND APPLY THE PREFERRED POLYMER, DEVELOPMENT OF A QUALITY ASSURANCE PROGRAM, ASSURE TOXILOGICAL AND ENVIROMENTAL REQUIREMENTS ARE MET, AND DOCUMENTATION OF PERFORMANCE ADVANTAGES.[2]

BALANCING OUR R&D INVESTMENT PORTFOLIO WITH THE CORRECT LEVEL OF SHORT TERM/LOW RISK DEVELOPMENT EFFORTS, MEDIUM TERM/HIGHER RISK APPLIED RESEARCH AND LONG TERM/HIGH RISK, BUT HIGHLY BENEFICIAL BASIC RESEARCH, IS ONE CRITICAL ISSUE THAT NEEDS TO BE RESOLVED. TODAY'S TRANSPORTATION R&D ACTIVITIES DOES NOT HAVE A GREAT DEAL OF RESEARCH AS EVIDENCED BY THE ANNUAL INTERNATIONAL ROAD FEDERATION SURVEY[3]. MY ESTIMATE FROM THIS SURVEY IS THERE IS ONLY ABOUT 20% RESEARCH EFFORT WITH ABOUT 80% OF THE FHWA STAFF AND CONTRACT RESEARCH EFFORTS FOCUSED ON VARIOUS DEVELOPMENT TYPE FUNCTIONS AND IN PREPARING MANUALS, DOING SURVEYS AND ANALYSIS OF ENVIRONMENTAL IMPACTS. THIS IS NOT TO IMPLY THESE EFFORTS ARE NOT IMPORTANT AND NECESSARY, BUT RATHER THEY DO NOT REPRESENT THE TYPE OF LONGER RANGE ACTIVITIES NEEDED TO CREATE SIGNIFICANT BREAKTHROUGHS IN IMPROVED PERFORMANCE AND SAFETY OF OUR NATIONAL HIGHWAY SYSTEM.

THIS LEADS THEN TO THE SECOND AREA FOR IMPROVED R&D INVESTMENT AND THAT IS THROUGH THE USE OF STRATEGIC PLANNING. THERE HAVE BEEN NUMEROUS PUBLICATIONS EXTOLLING THE NEED FOR A TRANSPORTATION POLICY IN THE UNITED STATES.[4,5,6] YOUR LEADERSHIP IN ENACTING THE SURFACE TRANSPORTATION ASSISTANCE ACT OF 1982 RECOGNIZED OUR CONTINUING NATIONAL NEED FOR A GOOD, SAFE HIGHWAY NETWORK AND PROVIDED INCREASED FUNDING FOR RESURFACING, RESTORATION, REHABILITATION, AND RECONSTRUCTION OF THIS NETWORK.

THESE HEARINGS TODAY ARE A NECESSARY STEP IN ESTABLISHING A COMPLETE TRANSPORTATION POLICY. WHERE WE WANT TO PUT OUR RESEARCH AND DEVELOPMENT EMPHASIS IS CRITICAL IF WE ARE TO (A) PROVIDE OUR SCIENTISTS WITH THE DIRECTION NEEDED TO OPTIMIZE THEIR RESEARCH EFFORTS AND (B) ASSURE THAT OUR HIGHWAY ENGINEERS HAVE THE MODERN, CURRENT TECHNOLOGY NECESSARY TO OPTIMIZE THE PERFORMANCE OF THE NEW AND RECONSTRUCTED ROADS AND BRIDGES. THE POSSIBLE DIRECTIONS FOR OUR RESEARCH ACTIVITIES ARE MANY, ALL OF WHICH SHOULD IMPROVE PRICE/VALUE RELATIONSHIPS AND COULD INCLUDE, (1) METHODS TO LOWER CONSTRUCTIONS COSTS, (2) IMPROVED PERFORMING HIGHWAY SYSTEMS, I.E. MORE DURABLE, ENERGY EFFICIENT ROAD SURFACES, (3) SAFER HIGHWAY SYSTEMS; I.E. ROADS AND VEHICLES WHICH SIGNIFICANTLY REDUCE THE HIGHWAY DEATHS AND INJURIES SUFFERED EACH YEAR, AND (4) DESIGNS WHICH HAVE INHERENTLY LOWER MAINTENANCE COSTS. I AM NOT PRESUMING TO ADVISE ON THE SPECIFIC STRATEGIES OR DIRECTIONS WHICH SHOULD BE GIVEN, RATHER, ONLY TO EMPHASIZE THAT PROVIDING THOSE DIRECTIONS WILL ASSURE WE RECEIVE A BETTER VALUE[7] FOR OUR R&D INVESTMENT. THE OBJECTIVE OF STRATEGIC DIRECTION IS TO STRUCTURE OUR RESEARCH, HELP INSURE WE ARE WORKING ON THE MAJOR PROBLEMS AND THAT THE RESULTS WILL HAVE MAXIMUM IMPACT, UTILITY, AND BENEFIT.

SPECIFIC DIRECTIONS ON R&D NEEDED TO IMPROVE OUR HIGHWAY TRANSPORTATION SYSTEMS APPEARS TO BE ONE AREA WHERE GOVERNMENT LEADERSHIP IS NOT ONLY NEEDED, BUT WHERE LEADERSHIP IS APPROPRIATE. WE HAVE TODAY VERY GOOD TACTICAL LEADERSHIP, BUT LACK THE STRATEGIC DIRECTIONS ON WHERE WE WANT OUR HIGHWAY SYSTEM TO BE 5, 10, 20 YEARS FROM NOW - AND WHAT ARE THE MAJOR TECHNICAL INNOVATIONS NEEDED TO ACHIEVE THOSE OBJECTIVES. IT IS MOST PROBABLE THAT GREATEST EFFICIENCIES WOULD ALSO BE ACHIEVED IF THE FEDERAL GOVERNMENT PROVIDED THAT LEADERSHIP. HOPEFULLY, HOWEVER, LOCAL AND STATE GOVERNMENT WOULD ASSIST THE FEDERAL GOVERNMENT IN DEVELOPING STRATEGIC DIRECTIONS FOR OUR HIGHWAY TRANSPORTATION SYSTEM. IT WOULD ALSO BE HIGHLY

DESIRABLE FOR THE VARIOUS PRIVATE SECTORS; I.E. SUPPLIERS, CONTRACTORS, INDEPENDENT RESEARCH ORGANIZATIONS, ETC., TO ASSIST IN DEVELOPING THIS DIRECTION.[8]

IN ADDITION TO RECOGNIZING THE VALUE OF STRATEGIC PLANNING IN IMPROVING OUR R&D INVESTMENT, WE HAVE ALSO, MORE RECENTLY, FOUND THAT DEVELOPING AN EFFECTIVE STRATEGIC PLAN INVOLVES ALL FUNCTIONS IN OUR COMPANY, NOT JUST MARKETING OR R&D. THE SYNERGISM THAT RESULTS FROM INTEGRATING THE VARIOUS BACKGROUNDS LEADS TO A PLAN THAT HAS BOTH BETTER ANALYSIS AND RESULTANT COMMITTMENT. WE HAVE AT 3M ATTEMPTED TO CREATE A VISIONARY COMMITTEE FOR EACH MAJOR BUSINESS AREA CALLED A STRATEGIC PLANNING UNIT. MEMBERSHIP IS MADE UP OF EXPERIENCED AND CONTRIBUTING INDIVIDUALS FROM EACH MAJOR FUNCTION. IT SHOULD BE POSSIBLE TO FORM SUCH A PSEUDO AGENCY FOR HIGHWAY TRANSPORTATION SYSTEMS, WHICH IS COMPRISED OF A SMALL NUMBER OF EXPERIENCED INDIVIDUALS REPRESENTING THE POLITICAL, PROFESSIONAL, AND USER SEGMENT OF THE HIGHWAY SYSTEM AND REPRESENTING THE NATIONAL THROUGH LOCAL LEVELS OF GOVERNMENT - TO DEVELOP THE STRATEGIC DIRECTION FOR OUR FUTURE NATIONAL HIGHWAY SYSTEM. THE STRUCTURE OF THESE HEARINGS, WHERE INPUT FROM DIVERSE ORGANIZATIONS IS BEING PRESENTED, IS A STEP IN THE DIRECTION FOR INTEGRATED STRATEGIC PLANNING ON OUR TRANSPORTATION SYSTEM.

THE THIRD AREA I WISH TO PRESENT TODAY IS METHODS TO ENCOURAGE INCREASED PRIVATE INVESTMENT IN HIGHWAY R&D. THERE HAVE BEEN NUMEROUS ARTICLES WRITTEN ABOUT THIS SUBJECT; IN ADDITION FIVE GOVERNMENT COMMISSIONS AND TASK FORCES WITHIN THE PAST 15 YEARS HAVE ALSO PROPOSED ACTIONS ON IMPROVING PRIVATE INNOVATION.[9,10] MY INTENT TODAY IS NOT TO REVIEW ALL OF THESE ALTERNATIVES, BUT RATHER TO FOCUS ON TWO WHICH COULD HAVE THE GREATEST IMPACT. BOTH ARE PRINCIPLED BY "MARKET DRIVEN" VERSUS TECHNOLOGY DRIVEN R&D.

THE FIRST OF THESE ENCOURAGEMENTS IS BY PROVIDING STRATEGIC DIRECTION. DEFINING THE SPECIFIC AREAS WHERE HIGHWAY LEADERS ARE SEEKING INNOVATION WILL GIVE PRIVATE INDUSTRY GREATER CONFIDENCE IN OUR R&D INVESTMENTS. IT WILL ALSO INCREASE THE ACCEPTANCE OF THESE INNOVATIONS, SINCE YOU ARE HELPING TO "PULL" THESE IMPROVEMENTS THROUGHT THE RESEARCH AND DEVELOPMENT PROCESS. WITHOUT THIS FOCUS WE WILL NOT ONLY BE SPENDING SIGNIFICANTLY MORE ON R&D, BUT WE WILL BE WASTING A VALUABLE NATIONAL RESOURCE, THE MISDIRECTION OF OUR TECHNICAL AND SCIENTIFIC PEOPLE.

A SECOND METHOD TO ENCOURAGE GREATER INDUSTRIAL R&D ON OUR TRANSPORTATION SYSTEM IS TO CHANGE GOVERNMENT PROCUREMENT PROCEDURES. TODAY'S HIGHWAY PURCHASING STANDARDS ARE GENERALLY BASED ON MINIMUM PERFORMANCE SPECIFICATIONS AND LOW BIDS. THERE IS LITTLE ECONOMIC INCENTIVE FOR INDUSTRY TO PROVIDE ADDED VALUE, UNLESS THE SPECIFICATION CAN BE CHANGED. IN FACT, MANY GOVERNMENT PURCHASING UNITS SPECIFICALLY DISALLOW PROPRIETARY PRODUCTS, AND THUS CANNOT UPGRADE SPECIFICATIONS. THERE IS PERHAPS AN INCENTIVE TO PROVIDE LOWER QUALITY AND THUS LOWER VALUE PRODUCTS. HIGHWAY CONSTRUCTION PRACTICES EVEN RECOGNIZE THIS IN SOME CASES WITH FORMULAS WHICH REDUCE PAYMENTS FOR BELOW SPECIFICATION WORK. WHY THEN CANNOT WE REWARD THOSE CONTRACTORS OR SUPPLIERS FOR HIGHER QUALITY PRODUCTS OR SERVICES? THIS HAS AND IS BEING DONE, AS EXAMPLED BY INCENTIVES FOR EARLY COMPLETION OF RECONSTRUCTION, BUT COULD BE EXPANDED. VALUE ADDED PURCHASING DECISIONS COULD NOT ONLY ENCOURAGE INCREASED PRIVATE INVESTMENT IN R&D, IMPLEMENTATION COULD ALSO INCREASE THE SAFETY AND PERFORMANCE OF OUR NEW ROADS AND BRIDGES AND DECREASE TOTAL SYSTEM COSTS. IT COULD ALSO IMPROVE THE DECISIONS OF OUR TRAFFIC AND TRANSPORTATION ENGINEERS, SINCE THEY WILL BE EXPOSED TO HIGHER PERFORMING ALTERNATIVES, RATHER THAN MINIMUM PERFORMANCE STANDARDS.

THE FINAL AREA I WISH TO OFFER TODAY IS A TECHNIQUE WHICH IS FINDING INCREASING USE IN INDUSTRIAL R&D. THAT TECHNIQUE IS THE USE OF STATISTICAL METHODS IN IMPROVING THE COST EFFECTIVENESS, PRODUCTIVITY AND VALUE OF OUR RESEARCH ACTIVITIES. ALL OF YOU ARE FAMILIAR WITH THE INCREASING USE AND POWER OF STATISTICS. THE APPLICATION OF STATISTICS TO R&D AND INDUSTRIAL PROCESSES IS CALLED DATA ANALYSIS. DATA ANALYSIS CAN AND IS APPLIED TO ALL PHASES OF A PRODUCT[11], FROM APPLIED RESEARCH THROUGH DEVELOPMENT, EVALUATION TO PRODUCT SCALE-UP, PRODUCTION AND PRODUCT CONTROL. IN FACT THE CONSISTENT APPLICATION THROUGH ALL PHASES OF A PRODUCT'S LIFE CYCLE HELPS INCREASE THE BENEFITS OF DATA ANALYSIS. THE INCREASING USE OF DATA ANALYSIS IS BECAUSE THE TECHNIQUE OFFERS SIGNIFICANT INCREASES IN PRODUCTIVITY; THIS IS BECAUSE OF THE POWER, EFFICIENCY, AND INCREASED CONFIDENCE RESULTING FROM THE USE OF STATISTICAL OR DATA ANALYSIS.

DATA ANALYSIS HAS "POWER" BECAUSE IT ALLOWS THE SCIENTIST TO ANALYZE VERY COMPLEX SITUATIONS. IT ALLOWS US TO LOGICALLY IDENTIFY THE VARIOUS FACTORS WHICH AFFECT PERFORMANCE. IT ALSO ALLOWS US TO DEFINE THE QUANTITATIVE EFFECTS OF THOSE VARIABLES ON PROPERTIES AND THE INTERACTION OF VARIABLES. THIS QUANTITATIVE INFORMATION CAN THEN BE USED IN A NUMBER OF WAYS; (1) BALANCE OR OPTIMIZE SEVERAL CONFLICTING PRODUCT PROPERTIES (2) CONTROL ANY SPECIFIC PERFORMANCE PROPERTY BY CONTROLLING THE VARIABLES SUCH AS RAW MATERIALS WHICH AFFECT THAT PROPERTY, (3) IMPROVE TOTAL PRODUCT QUALITY BY CONTROLLING AND MINIMIZING VARIABILITY AND (4) GENERALLY REDUCE THE COST OF PRODUCING HIGH QUALITY PRODUCTS.

THE PRODUCTION OF HIGHWAYS AND BRIDGES APPEARS TO BE AN EXCELLENT, BUT NEGLECTED AREA FOR THE USE OF DATA ANALYSIS. THE "PRODUCTION" PROCESSES USED TO PRODUCE HIGHWAYS ARE COMPLEX, LABOR INTENSIVE, HAVE A GREAT DEGREE OF INHERENT RAW MATERIAL VARIABILITY AND HAVE HIGHLY DEMANDING PERFORMANCE

AND DURABILITY REQUIREMENTS. THERE HAS BEEN A SIGNIFICANT AMOUNT OF WORK DONE ON IDENTIFYING THE VARIABLES WHICH CAN AFFECT PERFORMANCE, BUT THE EFFECT OF THESE VARIABLES IS GENERALLY KNOWN ONLY QUALITATIVELY. CONSIDER FOR A FEW MOMENTS THE VALUE TO OUR HIGHWAY ENGINEERS IF THESE VARIABLES WERE KNOWN QUANTITATIVELY; WE COULD THEN DEAL WITH THE LARGE DIFFERENCES IN RAW MATERIALS AND CONSTRUCTION METHODS TO CONTROL AND OPTIMIZE THE PROPERTIES OF OUR HIGHWAYS. WE COULD FOCUS APPLIED RESEARCH ON IMPROVING THOSE SPECIFIC VARIABLES WHICH AFFECT DURABILITY OF ROADS, IF INCREASED DURABILITY WERE ONE OF OUR STRATEGIC DIRECTIONS.

KNOWING THE QUANTITATIVE RELATIONSHIP OF THESE VARIABLES CAN ALSO HELP THE CONFIDENCE OF OUR DECISION PROCESSES. MOST OBVIOUS IS THE TEST PLAN FOR ASSURING A CONSTRUCTION MEETS OR EXCEEDS A CRITICAL PERFORMANCE PARAMETER. COST/BENEFIT DECISIONS CAN BE MADE WITH MORE CONFIDENCE SINCE YOU NOW KNOW THE QUANTITATIVE EFFECT ON PERFORMANCE BY CHANGING THE "LEVEL" AND THUS THE COST OF ONE VARIABLE.

ANOTHER USE OF DATA ANALYSIS TECHNIQUES IS IT ALLOWS YOU TO CONTINUALLY IMPROVE PROPERTIES EVEN DURING THE STANDARD PRODUCTION OF A PRODUCT. THIS METHODOLOGY IS CALLED EVOP OR EVOLUTIONARY OPERATIONS AND HAS AS A CONCEPT THE PHILOSOPHY THAT PRODUCTION PROCESSES SHOULD NOT JUST PRODUCE PRODUCTS, THEY SHOULD ALSO PRODUCE INFORMATION OR KNOWLEDGE. EVOP IS THE SMALL PERTURBATION OF A FEW VARIABLES DURING NORMAL PRODUCTION TO FIND AREAS OF HIGHER PERFORMANCE. IT IS REALLY THE FINE TUNING OF A PROCESS, BUT DOES OFFER AN INEXPENSIVE AND LOW RISK METHOD TO GATHER KNOWLEDGE AND GAIN IMPROVEMENT.

THE METHOLOGY OF EVOP COULD BE APPLIED TO THE PROCESS OF CONSTRUCTING ROADS AND BRIDGES. IN ITS ULTIMATE FORM, EVERY MILE OF ROAD WOULD SERVE TWO PURPOSES; ONE AS A TRANSPORTATION SURFACE AND THE SECOND AS A DATA POINT

FOR AN EXPERIMENT WHICH WILL HELP EVOLVE IMPROVED TRANSPORTATION SYSTEMS.

THE BASIC CONCEPT BEHIND ALL DATA ANALYSIS TECHNIQUES IS THE RECOGNITION THAT WE LIVE IN A WORLD OF VARIABLES. DATA ANALYSIS ALLOWS US TO USE THESE VARIABLES TO OUR BENEFIT, RATHER THAN LETTING VARIABILITY CAUSE UNEXPECTED AND UNDESIRABLE RESULTS WHICH ARE ALWAYS EXPENSIVE AND IN MANY CASES ARE TRAGIC.

IN SUMMARY, I BELIEVE WE CAN SIGNIFICANTLY IMPROVE OUR INVESTMENT IN HIGHWAY TRANSPORTATION R&D IF WE (1) STRATEGICALLY DEFINE THE FUTURE REQUIREMENTS AND DESIRES FOR OUR NATIONAL HIGHWAY SYSTEM USING A BALANCED INPUT FROM ALL KNOWLEDGEABLE SOURCES, INCLUDING PUBLIC, PRIVATE AND PROFESSIONAL (2) BALANCE THE BASIC, APPLIED RESEARCH AND PRODUCT DEVELOPMENT EFFORTS AND DIRECTION TO BEST MEET THESE STRATEGIC OBJECTIVES (3) ENCOURAGE INCREASED PRIVATE INVESTMENT IN TRANSPORTATION R&D BY CHANGING PURCHASING PROCEDURES SUCH THAT THEY ENCOURAGE, RATHER THAN DISCOURAGE, INNOVATION, AND (4) APPLY STATISTICAL TECHNIQUES WHICH HAVE PROVEN BENEFITS IN IMPROVED EFFICIENCY, PRODUCTIVITY, AND CONFIDENCE, TO RESEARCH, DEVELOPMENT AND ALL NORMAL PRODUCTION ON HIGHWAYS AND BRIDGES.

I HOPE THESE SUGGESTIONS ARE OF SOME VALUE TO THE DELIBERATIONS OF THESE COMMITTEES. IF YOU HAVE ANY QUESTIONS, I WOULD BE HAPPY TO TRY TO ANSWER THEM.

1. Accident Facts, 1982 Edition, National Safety Council.

2. F.H. Healey, Research Management, November, 1978, p. 12-16.

3. International Road Federation, 1980 World Survey of Current Research and Development on Roads and Road Transport, December 1980, p. 540-585.

4. R.B. Reich, Harvard Business Review, Jan.-Feb., 1982, p.74-81.

5. B. Rubinge, Sloan Management Review, Spring, 1983, p. 43-53.

6. ARTBA Policy Statement, Feb. 23, 1983.

7. E. Mansfield, Research Management, July, 1982, p. 23-29.

8. J. Aiko, Japan-American Society, Washington D.C., April 1, 1982.

9. W.A. Fischer and G. Black, Research Management, September, 1979, p. 27-30.

10. J.B. Quinn, Research Management, November, 1977, p. 11-18.

11. Data Analysis Course, Unpublished, 3M Company.

IMPROVED

R & D

PRODUCTIVITY

STRATEGIC PLANNING

TECHNICAL PLANNING

PRIVATE INDUSTRY COMMITMENT

OPERATIONAL METHOD

STRATEGIC PLANNING

DIRECTION

FUTURE NEEDS

LIMITATIONS

SYNERGISTIC INPUT

BALANCED R & D

BASIC - LONG TERM

APPLIED - DIRECTED

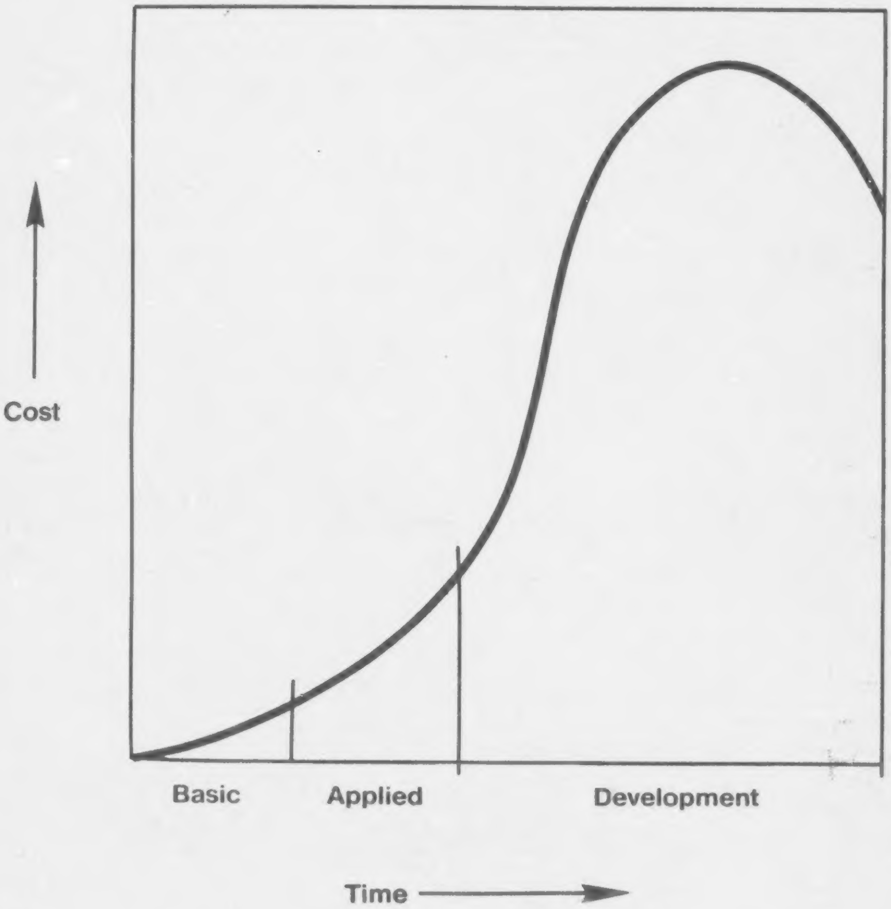
DEVELOPMENT- SHORT TERM

SERVICE - IMPLEMENTATION

RELATIVE FACTORS

	COST	VALUE TIME/WORTH/RISK
BASIC	LOW	HIGH
APPLIED	MEDIUM	MEDIUM
DEVELOPMENT	HIGH	LOW

Cost vs Research



PRIVATE COMMITMENT

DIRECTION

VALUE ADDED INCENTIVE

DIRECTION

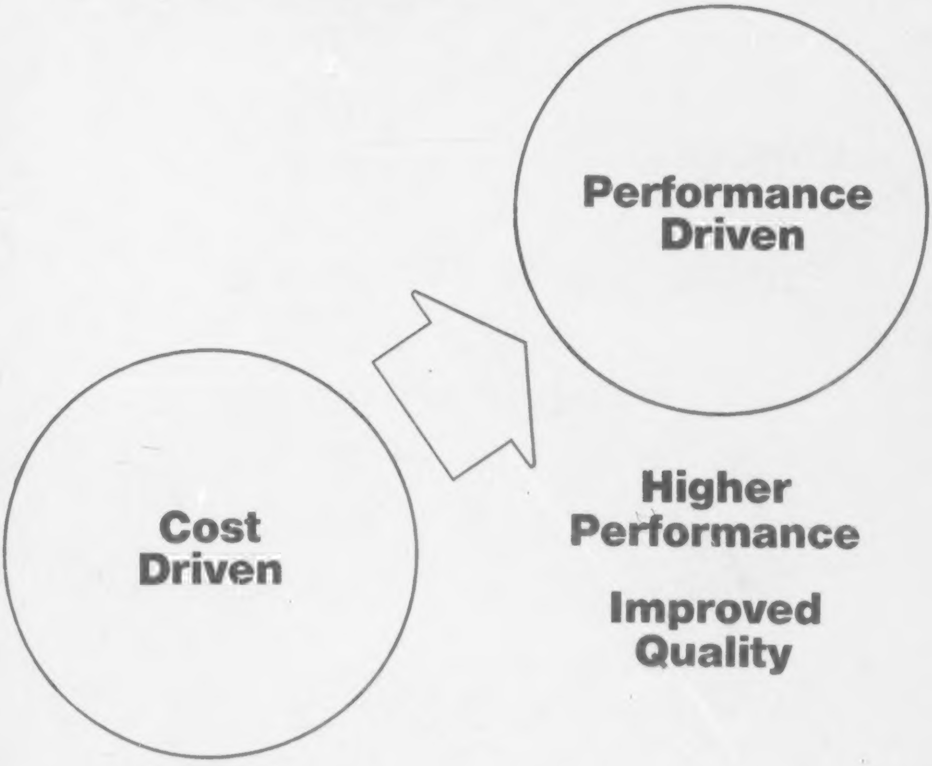
CONFIDENCE

"MARKET" DRIVEN

- SHORTEN TIME SCALE
- ACCEPTANCE

STRATEGIC PLANNING

Value Added



Performance Driven

Cost Driven

Higher Performance

Improved Quality

Low Bid

Minimum Performance

DATA ANALYSIS

- SAMPLING
  - ANALYSIS OF VARIANCE
    - EXPERIMENTAL DESIGN
      - RESPONSE SURFACE METHODOLOGY
        - EVOLUTIONARY OPERATIONS
          - RELIABILITY

EXPERIMENTAL DESIGN

SCREENING STUDIES

IDENTIFY VARIABLES - WHICH

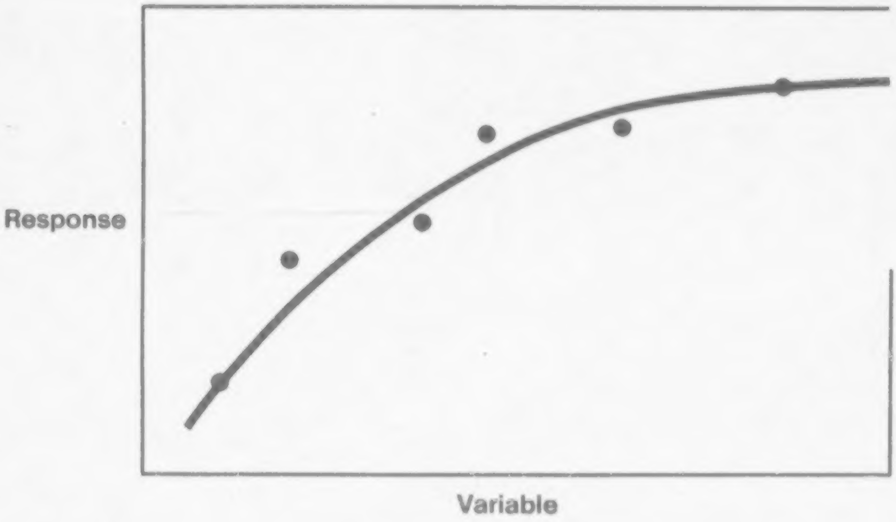
EMPIRICAL STUDIES

QUANTITATIVE RESPONSE - HOW

THEORETICAL STUDIES

BASIC/APPLIED RESEARCH - WHY

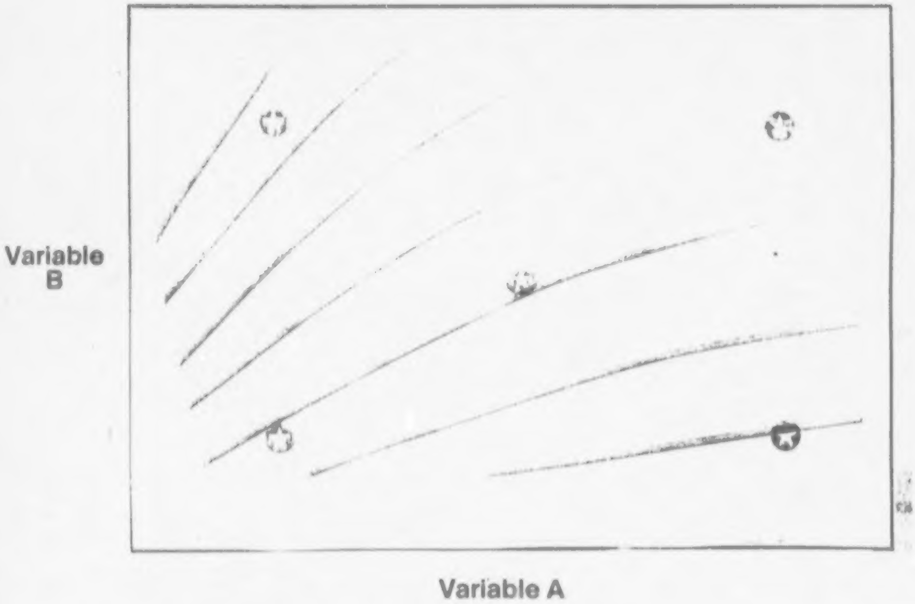
Classical Experimentation



Single Variable Analysis

Change One Variable
Hold World Constant
Measure One Response

Designed Experiments


Variable B
Variable A

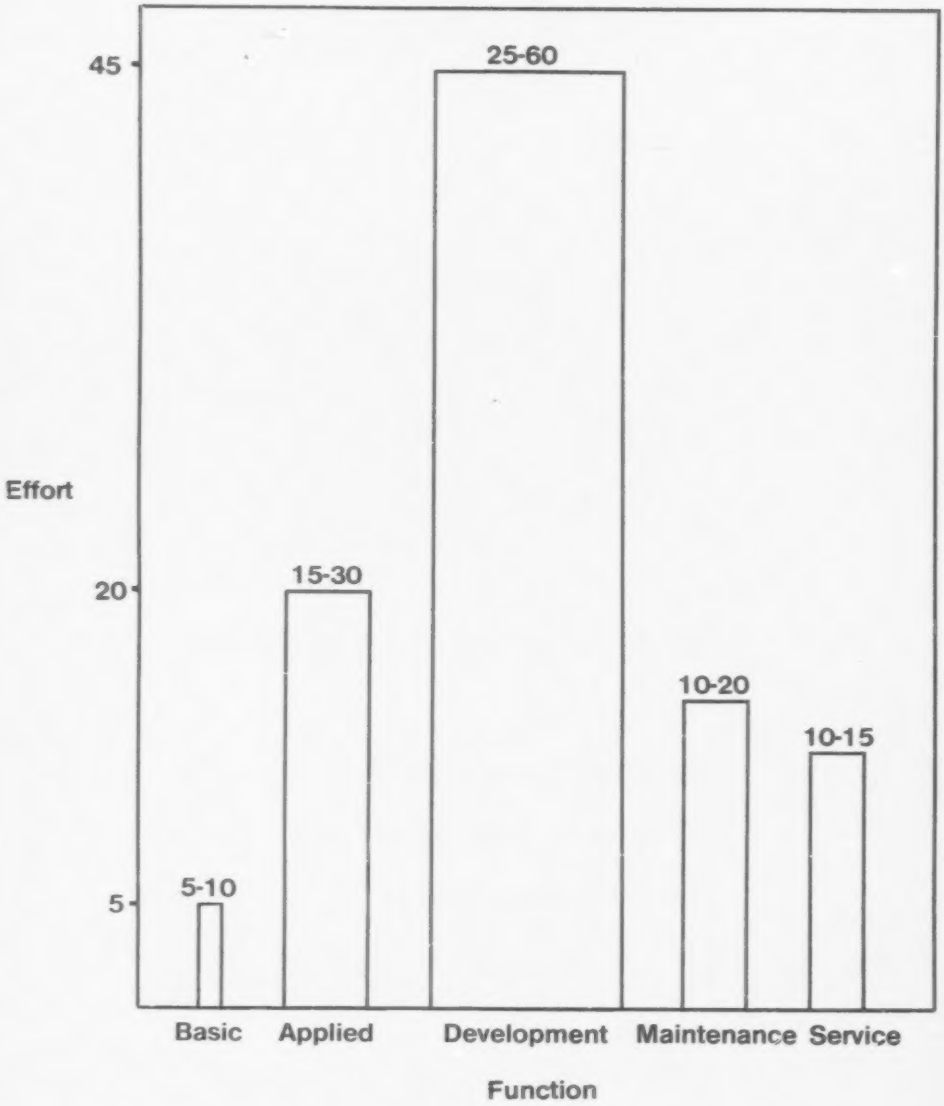
Multi-variable Analysis

Change Variables Controllably

Duplicate One Condition

Measure Responses

Technical Function vs Relative Effort



Mr. GLICKMAN. Thank you both for your interesting testimony. I would like to ask Dr. Gomory this question, and Dr. Erickson maybe would respond to the same question; 3M may be doing more highway-related research than IBM, at least directly, although indirectly you are obviously involved in every sector of the economy, I would think.

We heard testimony last week that highway transportation research and development is mostly decentralized and diffused, resulting in many different projects, but mostly very small-scale types of projects, like the effect of salt on either iron or other kinds of materials. While much good has come from such research operations over the years, we have heard that difficulties arise when there is a need to aggregate and focus large efforts on difficult interdisciplinary, multifaceted problems, where a large-scale or a critical mass of effort is needed.

Now, Dr. Gomory, today you say that there is no point in doing things halfway, that scale of activity is very important. First of all, I would like to get your opinions as to how that scale of activity can be applied to the specific subject matter we're talking about today—highway research. Is there a way to do it given the kind of decentralized nature of highway research? Second of all, let's say at your companies, IBM and 3M, how do you decide on the appropriate scale of a research project or activity? How much do you spend each year on R&D? What's the range of the size of the projects? I assume you have big projects and little projects that you do. So I wonder if you might deal with the specific question of highway research, and then get to your own companies.

Dr. GOMORY. Well, I would prefer not to talk about how this could be organized in the area of highways. I don't feel that I have any expertise in that. I am perfectly happy to reply, though, both as to how we decide on R&D and also on the scale of projects and the great variation of scales encountered.

In fact, we don't really decide ever on an R&D number at IBM. What happens is it falls out as a consequence of our doing those things that we feel are necessary. In other words, in order to bring out our disk products, we feel it is necessary to conduct certain projects. In order to bring out our printer products, we feel it is necessary to conduct certain projects. There is, indeed, a number, a percent. It often appears as a percent of sales, whatever it is, 7 percent or something. It is purely a fallout from a great many individual decisions. So we don't have a policy, really, about R&D. It is a very project-oriented game.

Similarly, the same remark I would make with respect to the scale of the project. In other words, we will tend to work backward. What do we have to do to make a new disk coating. There are just a lot of things that have to be investigated. We will simply total what we think are the numbers of people required, and that is what sets the scale of the project and also why you have an enormous variability, because to study, for example, the hammer mechanism, you can do that very effectively with five people, who can write the mathematical equations, do the programing, and in essence study the flight of the thing with about five to seven people.

On the other hand, to develop the disk coatings, the binder, the wear, that is a totally different scale of effort which I would say is much more on the level of 70 or 80, possibly even 100 people.

So all I can say is, we have an idea of the sort of thing we need to do, and we flesh that out project by project, and then all the numbers like expenditure and R&D are just totalling those individual projects.

Mr. GLICKMAN. I assume this is in your annual report, but what do you spend on R&D?

Dr. GOMORY. It's over $1.5 billion a year. The company sales are on the order of $30 billion.

Mr. GLICKMAN. And how many projects are you working on at any one time?

Dr. GOMORY. I don't know that number, because it is too divisionalized. That is, the disk people have their set of projects, the CPU people. But it's many hundreds, many hundreds.

The 1½ billion, that probably represents the efforts of 30,000 people. So it is a big effort to push all these things.

Mr. GLICKMAN. Dr. Erickson?

Dr. ERICKSON. My comments would be similar. What we do is——

Mr. GLICKMAN. And if you could relate this to the highway research.

Dr. ERICKSON. My particular job right now as a program manager is to take what we would consider to be a complex but, in the context of a highway system, is a very simple problem—but let's assume it is similar in complexity. We find that you really can't deal with something that is complex, that you really have to break it down into its elements. As an example, we will have a group that is specifically looking at just the manufacturing equipment, another group looking at the processing, another group looking at materials, or alternate materials, and so on. Then you build that back up. You break it down into elements that you can kind of get your arms around, and then you build it back up again and make sure it fits that ultimate final need that you're looking for.

Again, our efforts are really also a fallout. There is a desire on the part of our company to spend a certain percentage of our sales dollar on research and development, but it really is something that more than happens and we use that target to make sure that we don't fall below that level, because we feel if we do fall below it, we——

Mr. GLICKMAN. What's your target?

Dr. ERICKSON. Somewhere between 5 and 7 percent of sales. If we fall below that, then our company won't be what we want our company to be, because we know we have to invest at least that much to maintain the kind of growth that 3M is, the division or our company.

Mr. GLICKMAN. Now let me go back to the highway program.

Dr. ERICKSON. OK. Again, my job as a program manager is the development of a new reflective sheeting, so again, what we have done, we have broken the thing down into elements. We have said what kind of work needs to be done, what knowledge exists, what knowledge doesn't exist, how much effort do we put in, for example, to the polymeric materials that are used, and to back up—in case one doesn't work, we have got alternate approaches to it.

Mr. GLICKMAN. Do you have competition in that field, or are you the primary——

Dr. ERICKSON. There's competition, three Japanese companies, and one other U.S. company, in sheetings.

Mr. GLICKMAN. Why don't we hold off now. We have the second of two bells. We'll be back in about 10 minutes.

[Whereupon, the subcommittees were in recess.]

Mr. GLICKMAN. The hearing will come to order. I'm sorry for the delay.

Last week we talked a little bit with some of the folks in the transportation sector about the rapid rate of turnover of persons in top management positions in some of the transportation related companies, as well as State and local government. This was suggested as a problem in sustaining a longer term consistent program of research in transportation, but particularly in government, in the Departments of Transportation in the States.

Do you have such turnover problems in the private sector in research management?

Dr. GOMORY. We don't have that so much as a problem, but I have certainly seen it occur in parts of the R&D effort. I can only say that, where it has occurred, we have paid a heavy price for it. I think there really is a tremendous loss of commitment and continuity and expertise by these turnovers.

Dr. ERICKSON. We have had it as a problem. It again goes back to the period of time of about the last 10 to 15 years. It was caused because of what we call upward mobility. You stay on the job 2 or 3 years, get yourself a promotion, move out—and that's primarily with the management level and not with the actual operation of the technical people. It's the technical management.

Mr. GLICKMAN. Another question I would like to ask concerns getting the end user involved. Your company, obviously you have different end users. Some of your end users are internal.

Again trying to deal with the substantive matter we have got here, the end users, of course, are always going to be private citizens who are using the highways. You have a whole different nature of end users when you're talking about road research and related activity than you do in the computer or business machine area. If you would have any suggestions as to improving the process of getting the end user involved, it would be helpful for us right now.

You see, you have both spoken about how you do your research, when, why, and the process. Road research probably has more of a near-term component than a lot of the other areas, because the problems are continually facing people due to the financial aspects of keeping our infrastructure up and the enormous public investment in doing it. We tend to spend all of our dollars and all of our effort just filling potholes. We don't have either the money, the time, nor the inclination to figure out how do you keep the asphalt from breaking down.

How do we improve upon that in this very, very critical area, by maybe getting some of the end user involvement earlier? Do you have any comments on that?

Dr. GOMORY. Well, I am not quite sure who would play the role of your end user, so my remarks may be off the target. I have never found any substitute for extensive visiting—in other words, you actually have to get to know whoever these end users are. In our case, it may be the people in manufacturing, it may be the people in our development labs that actually design the product, or it may be customers. I have never found any substitute for having our people visit them extensively. In fact, we send our people to live a year in different environments. It's called a sabbatical program. So they get to understand what is on the people's minds.

If you will forgive an amateur's remark, I would think that if you really wanted to affect, say, the traffic lights or the repairs of roads, I think the people doing the R&D have to spend a lot of time visiting the town and seeing what makes the people decide what to do, what they do, and what matters to them. That may sound a little grubby, but I think that kind of thing is actually necessary.

Mr. GLICKMAN. Do you have anything additional to add to that, Dr. Erickson?

Dr. ERICKSON. Several things. First of all, I am also an end user. You will notice that I am what is called a road commissioner in a community, which involves me in the purchasing decisions and in the inventory of my roads, and signs. So I learn then how to use signs from the purchasing standpoint, in addition to the development standpoint.

Another way that we involve the end user is in the analysis of the demographics of the population that uses the roads. As those demographics shift to an older and older age group, then the needs, for example, in signing, and maybe the needs in the roads themselves, change also. So we are today sponsoring research at the University of Michigan on that demographic effect. There is an FHWA contract that will be let shortly on that same subject. So that is an end user analysis type of situation.

In addition, we try to get the opinions of the traffic engineers that are involved in our area on where they see particular problems. What are the problems, in this case in signing materials, and finding out what makes their life easier is what our game is all about. Because we are here to provide products that make the job easier for that person or customer.

Mr. GLICKMAN. A final question would go to Dr. Erickson.

One of the things that strikes me about this is that Government, as a general proposition, in acting on behalf of the people as an end user, the Government historically has this crisis-to-crisis activity. The only place I think where Government has tended to foster research might be in the military, where its role is more future-oriented because of the technological pressures. The research funding relationship in Government to road building is a lot different than it is when you build a B-1 or an MX or an F-15 fighter.

But I would ask you particularly, Dr. Erickson, there was some testimony last week similar to yours about current Government procurement practices working against private sector R&D investments and innovation. Do you have any specific suggestions for changing or upgrading product specifications to encourage more highway R&D? That is, can the Government itself help the process out a bit?

Dr. ERICKSON. Since the Government is the purchaser, the Government has to help encourage that. I would not really feel qualified to comment any more than what I did. There are others at 3M more expert and, if you're interested, they could come out and provide that information.

Mr. GLICKMAN. OK. We thank you both for your excellent testimony today. We appreciate it.

Mr. GLICKMAN. Our next panel will be talking about developments in Portland Cement research and highway research generally. Dr. Della M. Roy, Penn State, Dr. Anthony Kelly, vice chancellor of the University of Surrey, Surrey, England, and the third participant is Dr. C. V. Wootan, director of the Texas Transportation Institute, Texas A&M.

I think the way we are going to do this is to ask Dr. Roy to go first, Professor Kelly to go second, and Dr. Wootan to go third.

Dr. Roy, I think your husband, if I'm not mistaken, was before our subcommittee a couple of weeks ago on materials——

Dr. ROY. That's probably right.

Mr. GLICKMAN. And was one of the finest witnesses that we have ever had. I would tell you that, so as not to put any pressure on you. [Laughter.]

Dr. ROY. He's my slide projectionist today.

Mr. GLICKMAN. Right. He had a way of making drawings ad hoc, you know, and making sense out of very complicated subject matter.

Anyway, it is a pleasure to have you all here. As I said before, your entire statements will appear in the record. You may feel free to summarize, and we would like it very much if you could keep your testimony under 10 minutes so that we have time to ask questions.

Dr. Roy.

STATEMENTS OF DR. DELLA M. ROY, PROFESSOR OF MATERIALS SCIENCE, THE PENNSYLVANIA STATE UNIVERSITY; DR. ANTHONY KELLY, VICE CHANCELLOR, UNIVERSITY OF SURREY, SURREY, ENGLAND; AND DR. C. V. WOOTAN, DIRECTOR, TEXAS TRANSPORTATION INSTITUTE, TEXAS A&M UNIVERSITY

Dr. ROY. Mr. Chairman, it is a pleasure and a privilege to testify before your committee. I am Della M. Roy, professor of materials science at the Pennsylvania State University, in the Materials Research Laboratory and the Department of Materials Science and Engineering. I have had extensive research experience in the field of materials, particularly in cement and concrete and ceramic materials which are all of the same class of materials.

I have recently chaired a committee study of the National Materials Advisory Board of the National Academy of Sciences, National Academy of Engineering, on the status of cement and concrete R&D in the United States, these being primary highway materials, which are of direct concern to the committee.

The field of materials research has been getting a great deal of attention recently in the administration, in the Congress, and in the scientific press. Materials research, of course, covers an enormous spectrum of materials, those that are of primary concern to IBM and 3M, for example, to the more mundane ones that are of more major interest in surface transportation. I think it is important first to pull together some of the important distinctions among the classes.

If I could have the first transparency please, I will illustrate in this table several points. We have represented several classes of materials.

First on the left side, ceramics, semiconductors, metals, composites, polymers and wood are the main classes of materials; the next column shows the length of time they have been used: the field of ceramics, including cement and concrete, has been around for tens of thousands of years. The latter materials also are unique in that they are humankinds largest volume product among all manufactured materials, with production rates of billions of tons per year, where metals are perhaps one billion; and the raw materials are available everywhere. So all effort that is put into the ceramic materials research obviously has payoff in many directions and will continue to do so for a long time, as they are not subject to the usual limitations as with petroleum and chromium, et cetera, that have limited supplies.

In the final columns of the table, with respect to the research personnel and R&D investment—those columns were left out of this transparency, but are present in the printed version—we have a much poorer picture for the first category, ceramic materials in general and cement and concrete research, of the type that I feel we need. Compared with the others, using grades from A to F, we might grade ceramic materials including cement and concrete somewhere in D to F in terms of total availability of trained personnel and of sustained R&D that is needed to do the job.

Mr. GLICKMAN. Just for clarification, your grades are, in a sense, like classroom grades?

Dr. ROY. Like classroom grades. I'm a professor.

Admittedly, these are qualitative estimates, but I think we have to overcome some four decades of neglect by the Nation in the general field of ceramics, including cement and concrete, called low temperature ceramic materials. There has not been a sustained effort during this past period, from which we would now benefit in the highway program.

I think the loss of U.S. position in some of our materials technology did not happen for us because we have all been making the best judgments; and the academic, industrial, and agency management must have made some serious errors during these past tens of years. These are some of the possible errors in R&D support in the technology of materials that I feel may be partly responsible.

First, the emphasis in materials science has been on the physics, rather than on the more mundane aspects of processing, or on synthesis and chemistry. Second, Government funding agencies and universities together have tended to neglect the applied sciences field, on the one hand trying to go straight to the practical applications, or at the other extreme pursuing every ivory tower type of research. We need this intermediate type targeted research.

Finally, within the materials communities, too much emphasis has been on metallurgy over ceramics, and within ceramics emphasis of high temperature processing, again neglecting the low temperature materials. They are sort of at the bottom end of the totem pole. Their performance, as you will see later in Dr. Kelly's testimony, can be rather striking; there are great opportunities in cement composites, concrete and related materials, for transportation and housing applications.

So chasing high technology alone will not do anything in my opinion for the economic or employment picture in the United States because the number of jobs are small, while in this highway materials area we have a huge number. It is essentially in the medium technology range that I would ask for increased emphasis during this period.

When Mr. Nixon's science adviser, Dr. Edward David, made his intensive national study of the areas for the greatest potential return on R&D, he had targeted highway materials and cement as being ones that could bear the most fruit. His words weren't heard too well, therefore, the status is pretty much the same as it was when he made the statement.

I had the opportunity to chair a committee of the National Materials Advisory Board on the status of cement and concrete research. This was a couple of years ago. We produced a report on the status of R&D at that time, which has not changed very much in the last couple of years. I think that pointing to some of the findings of the committee would be appropriate here as well.

Among the findings and conclusions we pointed to the fact that there were both technical and nontechnical areas requiring attention to correct the existing deficiencies and prevent gross neglect of this major part of our society, that the R&D was obviously inadequate. Then, we pointed out the critical challenges to be faced by these materials in new applications or those under more extreme conditions; our highways are now subject to more extreme conditions, which fits the challenges recognized earlier. Materials are being called to their utmost performance.

The third was an institutional factor, that a focal point for specialized R&D funding and technical training was required. Coordination and focus is needed in order for a limited amount of R&D to do its job.

The recommendations briefly included some which are very specifically targeted for the highway materials subject area. Certain research topical areas and studies were recommended in this report: One, that research on long-term durability and performance of materials in either new or extreme environments is highly needed; this included the studies of basic mechanisms, both regarding how the materials are prepared and formed, and relating to problems of durability. You have to know your materials starting at the beginning and continuing through to the end use conditions. Then recommendations were made for research for new applications and materials substitutions.

The areas of research experience that I have had, particularly in our university, Penn State, fit within areas related to cement and concrete and ceramic material applications in general. Citing some of these will give an example of certain achievements, but also some of the shortcomings resulting from the lack of sufficient followup.

There have been potential technological applications such as preparation of new superdense cements made under high pressure and temperature, which have rather extraordinary properties; the preparation of dimensionally stable cements for bore hole plugging and for radioactive waste management, where the goal is thousands of years durability; and a new low temperature ceramic waste form, a cement form, that would be nearest to a thermodynamically stable, really long-time stable system. Then, finally, we worked with some materials for highway surfaces that would be extremely durable, drawing from high-density, high-strength ceramic materials. The latter were actually taken to full scale testing in the New York Throughway system and showed excellent performance at toll booths and exits, places where there is high traffic and high performance demands placed upon them. But there was no followthrough.

This case I think is very much in line with an example that Dr. Erickson gave. You need a system that will follow through, not just take the material to the first stage of demonstration.

So, overall, I think there are tremendous research needs. There is somewhat of a policy vacuum and I am delighted that this committee is addressing that.

To summarize, then, the goals and mechanisms that I would see in the materials research area for application to highways, in terms of national priorities one should shift research priorities to science which is applied and purposive. This is still fundamental science, but it must have a purpose and a direction. This requires a sustained, coordinated, targeted input from all our groups, from the universities, from industry, and from Government as the user, for research on low temperature—I call them low temperature ceramics, concrete, cement—low energy content materials which will be a permanent part of the future. But again, this should be a sustained, not a short-term effort. The present effort simply won't do if we are to accomplish more than filling potholes, but develop instead better materials that will prevent potholes forming in the first place.

Regarding possible mechanisms for doing this, there are a number but I just cited two or three examples here. Congressman Brown's bill, H.R. 481, to generate a National Technology Foundation would be one way to accomplish this, by having the combination of applied research.

Another mechanism obviously is to earmark clearly part of the tax from the highway program for a coordinated research program. Now, I know this is the intention to do this, but it is necessary to make sure that a program has the required degree of coordination and is sustained over some years. For really innovative things to happen, it requires the 5- to 10-year timeframe, not simply limiting the effort to what is needed for fixing the first bridge. In this, there should be the participation of the major concerned universities and industries, in a network with the DOT or National Technology Foundation or coordinated by PCA, NBS, and the relevant governmental bodies.

Thank you.

[The prepared statement of Dr. Roy follows:]

Testimony of Professor Della M. Roy

The Pennsylvania State University

before the

House Committee on Science and Technology

June 15, 1983

IMPORTANCE OF CEMENT, CONCRETE AND LOW TEMPERATURE CERAMICS RESEARCH

Mr. Chairman, it is a pleasure and a privilege to testify before your committee on the importance of certain areas of research which are vital to public and private sector technologies in the United States.

The field of materials research has been getting a great deal of attention recently in the Administration, the Congress and the scientific press. Materials research covers an enormous spectrum of materials and in order to give you some feel for the important distinctions I have pulled together in Table 1 some of the simple parameters regarding the different families of materials.

Table I. MATERIALS TECHNOLOGIES

USE STARTED IN	MILLIONS OF TONS/YEAR	RESOURCES NEEDED	PRODUCTS	RESEARCH ACTIVITY	PERSONNEL AVAILABLE
CERAMICS (NON-METALLIC, INORGANIC) INCL. CEMENT 10,000 B.C.	1-10,000	SiO_2, Al_2O_3 CaO, MgO, Fe_2O_3 UNIVERSALLY AVAILABLE NO RESOURCE PROBLEM FOR ANY NATION	POTTERY GLASS-BULK OPTICAL CEMENT CUTTING TOOLS DIAMONDS TURBINES	F	F
SEMICONDUCTORS - 1940	-001	NO RESOURCE ISSUE (EXCEPT GA)	SMALL ELECTRICAL DEVICES	A	A^-
METALS 5000 B.C.	Fe:500 OTHERS: 500	VIABLE ORES GEOGRAPHALLY SPOTTY	MYRIAD USES STEEL, COPPER, ALUMINUM ALLOYS	B^-	B
COMPOSITES 1950	1	NOT IMPORTANT	FURNITURE-TO AIRPLANES	C	C
POLYMERS 1900 (ORGANIC-NONMETALLICS)	100+	PETROLEUM (NOW)	'CONTAINERS' TEXTILES:	A^-	B^-
WOOD - 300,000,000 B.C. (NATURAL COMPOSITES)	1-10,000	RENEWABLE, BUT SOMEWHAT GEOGRAPHICALLY LIMITED	BUILDING	D	B

We can use this table to make several points. First, we note that ceramic materials, including cement, are humankind's largest-volume product, among all manufactured products, with a production rate of a few billion tons/year where metals are near one. Second, we note that the raw materials needed for ceramics (SiO_2, Al_2O_3, CaO, etc.) are available everywhere and, as distinct from cobalt, chromium and petroleum, not subject to any international supply interruptions. Third, I want to point to the comparisons in the last columns of the relative R&D investment and personnel supply in the U.S., compared to Japan and Western Europe. These ratings are qualitative estimates but nevertheless reflect the poor position that four decades of neglect have led the nation into with respect to ceramics, including cement and other low-temperature inorganic materials.

Mr. Chairman, the loss of the U.S. position in technology did not happen because all of us have been making the very best judgments. The fact is that someone in the science and technology policy community--the academics, industry and agency management--must have made some serious errors at some time in the last 40 years. Let me list the possible errors made in the R&D support in the technology of materials.

1. Too much emphasis on the physics, and physical phenomena and analysis, and concomitant neglect of chemistry (synthesis, and processing) in university materials research.
2. Neglect by government funding agencies and the university community of applied science relevant to our industries and to public technologies (e.g., transportation, environment, etc.). Such research is typically interdisciplinary and harder to manage.
3. Emphasis on metallurgy over ceramics; and total neglect of

inorganic materials by chemistry departments.

4. And within ceramics research itself, neglect of low temperature materials of great relevance to industry, due to the attraction of federal dollars pulling research exclusively towards defense and space-oriented high performance materials.

Mr. Chairman, you know I am sure, that chasing high technology alone will do nothing for the economic or employment picture in the U.S. The number of jobs is small and they are the most easily lost. Putting our eggs in one basket has got us where we are. We need a balanced or optimum technology covering all ranges of sophistication matched to the people and resources of the U.S. Let me assure you that restoring balance between the materials technologies, high and medium, ceramics and metals, cannot be achieved by putting more money into the same old channels which led us astray in the first place. The Congress has to mandate changes in targets and objectives if the problem is to be addressed at all. My colleagues and I on the panel will give you data and information to suggest that some of the greatest technological opportunities are in areas of middle technology concerned with cement and related highway materials. The views expressed here are not idiosyncratic to us.

The Research Opportunity

When Mr. Nixon's science advisor, Dr. Edward David, made his intensive national study of the areas in which the greatest return on investment in research could be expected, the item that stood at the top was research into cement and highway materials. The status and opportunities for research in cement and concrete have been recently reviewed by a committee of the National Materials Advisory Board which I had the privilege to chair. I summarize them as Tables 2 and 3.

I believe that the world of materials research stands on the brink of a rather significant major shift. After the war we had an earlier major change towards polymeric or plastic materials away from metals. In the next twenty-five years, with energy cost and availability, and the metallic resource avilability issues looming large, combined with the emergence of new science, ceramic materials, especially low temperature ceramic materials, will become much more important in the national posture. The tables have presented some National Academy findings. Let me illustrate the point by alluding to the variety of research areas in which we at Penn State are finding really useful application for ceramics. Very few universities are active in cement research and indeed in ceramics, and Penn State has the largest research effort in this field. Some of the most interesting research on low temperature ceramic materials which has originated in the Materials Research Laboratory at Penn State which have possible industrial spin-offs are listed below:

- Novel fine powder technologies, especially the further development of the Decomposition of Misted Solutions (DMS) technique. The Austrians have a monopoly on this industry based on science done largely in our laboratories.
- New applications of the sol-gel technique especially to diphasic materials.
- Low temprature "hydrothermal" processing of ceramics.
- Utilization of natural raw materials such as clays, zeolites, etc., in low temperature ceramics.

TABLE 2

Conclusions: NMAB-361 Report:

The Status of Cement and Concrete R&D in the United States

- A number of areas, both technical and nontechnical, require attention to correct existing deficiencies and prevent gross neglect of this major building block of our industrial society
- Current level of R&D in cement and concrete in the U.S. is inadequate for an important area
- Critical challenges are faced for R&D to meet demands for new applications, and those under extreme conditions
- Resource availability predicts trend toward wider and more extensive applications of cement/concrete
- R&D in this area has suffered from lack of comprehensive national materials policy
- There is a need for a focal point for specialized R&D funding and technical training

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The Status of Cement and Concrete R&D in the U.S., Report No. NMAB-361, Committee on Status of Cement and Concrete R&D in the United States, National Materials Advisory Board, Commission on Sociotechnical Systems, 2101 Constitution Ave., NW, Washington, D.C. 20418 (1980).

TABLE 3

Recommendations, NMAB-361 Report

Studies along these major lines are recommended:

- Research on long-term durability and performance in either new or extreme environments is highly needed
- Studies of basic mechanisms of reactions in manufacturing and use of cement and concrete
- Research for new applications, processes and substitutions: Effective use of materials and other resources through use of cement and concrete composites as alternative materials
- Systems analyses and modeling of cement and concrete systems. Interdisciplinary studies, experimental and theoretical
- Studies relating to effective utilization of materials and other resources, including waste products and fuels

The University pioneered the basic science in each of these areas over a ten year period during the nineteen-fifties. The technological applications appeared 15-20 years later, but unfortunately it is not U.S. companies that will reap the majority of the benefits.

- New superdense cement made under pressure and temperature.
- Dimensionally stable cement for borehole plugging in radioactive waste management.
- New low temperature ceramic, radioactive waste forms, the most thermodynamically stable waste forms.
- New ceramic materials for highway surfaces, proved in full-scale tests in the New York State Thruway to have many times the durability of ordinary concrete.

I do not list here the extensive work in radioactive waste materials science, nor the dielectric-transducer area in which Penn State is the international center of university research.

The Policy Vacuum

I will not go further into the technical opportunities in detail because you wish also to know the policy implications of the condition we find ourselves in, which is in summary: (a) high opportunity area important to highways, buildings, ceramics in general; (b) very low research budgets; (c) very low personnel situation. What has been the Administration's policy response to this area where 'public technologies' are at stake, where the industry is so fragmented that it cannot mount any R and D effort?

The administration budget request for FY'84 provides 200 million dollars more for the National Science Foundation, the output of which research will not be felt for twenty years, and may well be felt abroad first, and at the same time the Administration eliminates the center for Building Research at the National Bureau of Standards. These are policies made by and for the high energy physics community. Certainly no one with any knowledge of the science or technology of materials could have had anything to do with such policies.

In my view this is exactly backwards with respect to priorities. Of course, I do not oppose, per se, additional funds for NSF, but Mr. Chairman, if science is to serve the national interest and not only the curiosity of scientists, we need to shift the priorities both of university research towards applied or purposive science; long-term and using the very highest science, of course, but with a direct link to our industry or public needs. This kind of long-term targeted science must become a major focus both within NSF and among mission agencies. What we need is something like what is envisaged as Congressman Brown's National Technology Foundation introduced as HR481. Without a structural change in U.S. institutions for research funding we cannot improve. We need especially a focus on, and new institutions with an avowed goal of funding applied science and technology. Without such changes areas of vital interest such as the materials research for highways will never receive appropriate attention. By far the most pressing reason for this is the enormous benefit/cost ratio of this research relevant for buildings and highways, impacting tens of thousands of workers and every citizen.

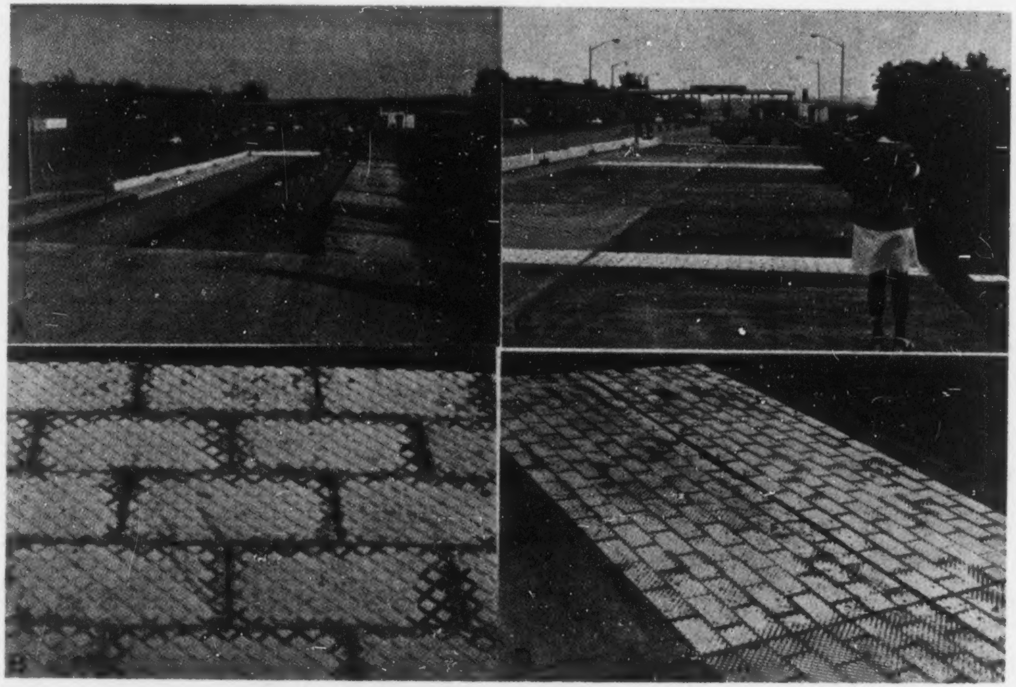
Goals and Mechanisms for Highway Related Materials Research

I believe that a coordinated, targeted, sustained, university-industry research progam on low temperature low-energy-content ceramic materials could have a really major and meaningful impact on the nation's highways (and buildings). The applications of the same classes of materials automatically extend from one to the other.

By coordinated I mean that the institutions which have the knowledge, equipment, personnel, etc., must all be networked into one program. They are in such short supply that competitive RFP's etc., are even more wasteful than in the other areas such as physics where we have oversupplies. We need a strong manager approach, as used in the Defense Department, who will pull together the nation's capabilities and address national problems.

By targeted I mean, that this is not a standard NSF or NIH approach of supporting two dozen individuals to write scientific papers. This will be a program using the very best science addressing the problems and opportunities in low temperature ceramics.

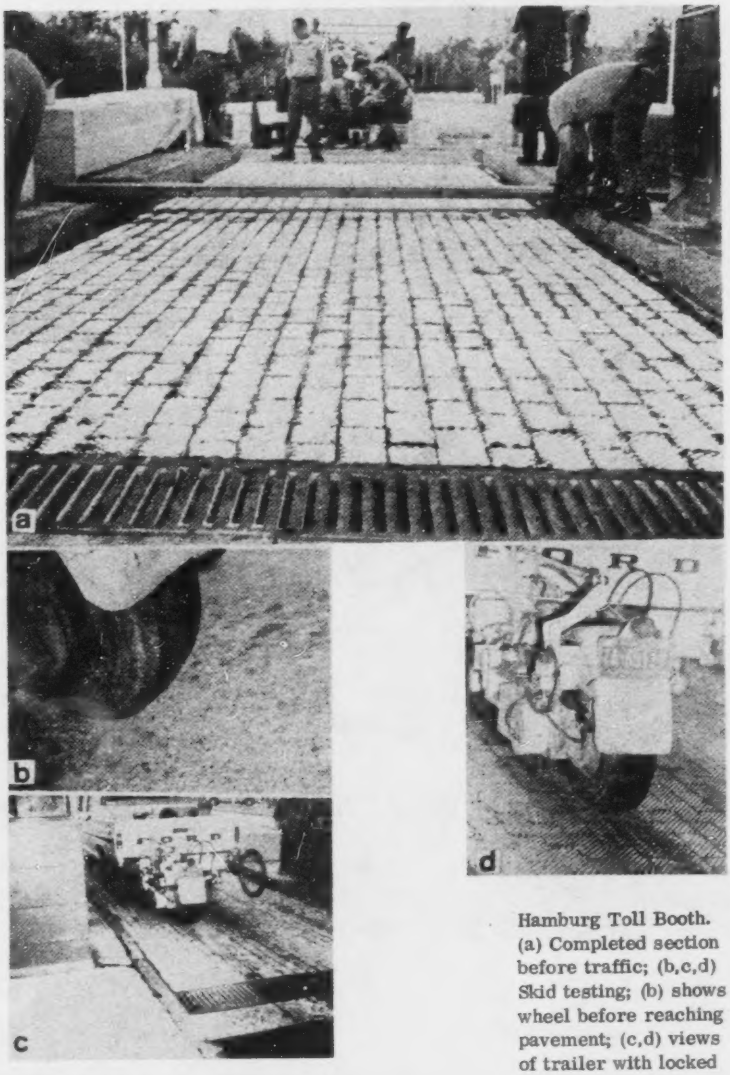
FIRST-COST IS THE ONLY PROBLEM



Victor Toll Plaza. A. Form work placed for concrete slabs, May 29; B, C and D: concrete and Durafrax in place, before traffic, June 26, 1976.

HIGH PERFORMANCE CERAMICS HAVE BEEN INSTALLED AND TESTED FOR 8 YEARS IN THE NEW YORK STATE THRUWAY.

FIRST-COST IS THE ONLY PROBLEM



Hamburg Toll Booth. (a) Completed section before traffic; (b,c,d) Skid testing; (b) shows wheel before reaching pavement; (c,d) views of trailer with locked wheel during test.

THESE CERAMICS WILL LAST 10-100X LONGER THAN CONCRETE AND WILL RETAIN MUCH SUPERIOR SKID RESISTANCE

PENN STATE CONTRIBUTIONS.

PSU/MRL'S BASIC SCIENCE ON LOW TEMPERATURE CERAMICS WITH POSSIBLE INDUSTRIAL SPIN-OFFS

- NOVEL FINE POWDER TECHNOLOGIES, DEVELOPMENT OF THE DECOMPOSITION OF MISTED SOLUTIONS (DMS) TECHNIQUE
- NEW APPLICATIONS OF THE SOL-GEL TECHNIQUE/ ESPECIALLY DIPHASIC MATERIALS
- LOW TEMPERATURE "HYDROTHERMAL" PROCESSING OF CERAMICS
- UTILIZATION OF NATURAL RAW MATERIALS SUCH AS CLAYS, ZEOLITES, ETC., IN LOW TEMPERATURE CERAMICS

GOALS/MECHANISMS : HIGHWAY-RELATED MATERIALS RESEARCH

GOALS

1. SHIFT RESEARCH PRIORITIES → APPLIED/PURPOSIVE SCIENCE

2. COORDINATED, TARGETED, SUSTAINED UNIVERSITY – INDUSTRY RESEARCH ON LOW-TEMP, LOW-ENERGY CONTENT, CERAMIC/CEMENT MATERIALS

NEW INSTITUTIONAL ARRANGEMENTS: COMBINE EXISTING STRENGTHS INTO NEW COUPLED NETWORKS**

- -

[illegible] MECHANISMS

- NATIONAL TECHNOLOGY FOUNDATION .. HR 481
- LEGISLATION: DEDICATE FIXED % OF TAX TO TARGETED COORDINATED RESEARCH FOR INNOVATIVE 5-10 YR TERM.

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* Major Universities

PENN STATE
MIT
ILLINOIS
UTAH
BERKELEY
PURDUE

* Major Industries:

CARBORUNDUM
NORTON
COORS
GE
MARTIN-MARIETTA.

NETWORK

↑

P.C.A. – N.B.S. D.O.T. (or N.T.F.)

POSSIBLE ERRORS IN R & D SUPPORT in TECHNOLOGY of MATERIALS

- TOO MUCH PHYSICS, NEGLECT CHEMISTRY, SYNTHESIS, PROCESSING
- NEGLECT BY FUNDING AGENCIES + UNIVERSITIES OF APPLIED SCIENCE RELEVANT TO INDUSTRIES, PUBLIC TECHNOLOGIES
- EMPHASIS ON METALLURGY over CERAMICS. NEGLECT OF INORGANIC MAT'L. BY CHEM. DEPT.
- WITHIN CERAMICS: NEGLECT OF **LOW** TEMPERATURE MATERIALS; EXCLUSIVE DEFENSE, SPACE - HIGH PERFORMANCE MAT.

HENCE GREAT OPPORTUNITY IN CEMENT, COMPOSITES, CONCRETE & RELATED MATERIALS IMPORTANT TO TRANSPORTATION & HOUSING.

Mr. GLICKMAN. I would want to make sure that that chart, if possible, could become part of the record.

Dr. ROY. Yes. I will get copies of that. I'm sorry.

[The information follows:]

GOALS/MECHANISMS : HIGHWAY-RELATED MATERIALS RESEARCH

GOALS

1. SHIFT RESEARCH PRIORITIES → APPLIED/PURPOSIVE SCIENCE
2. COORDINATED, TARGETED, SUSTAINED UNIVERSITY–INDUSTRY RESEARCH ON LOW-TEMP. LOW-ENERGY CONTENT, CERAMIC/CEMENT MATERIALS

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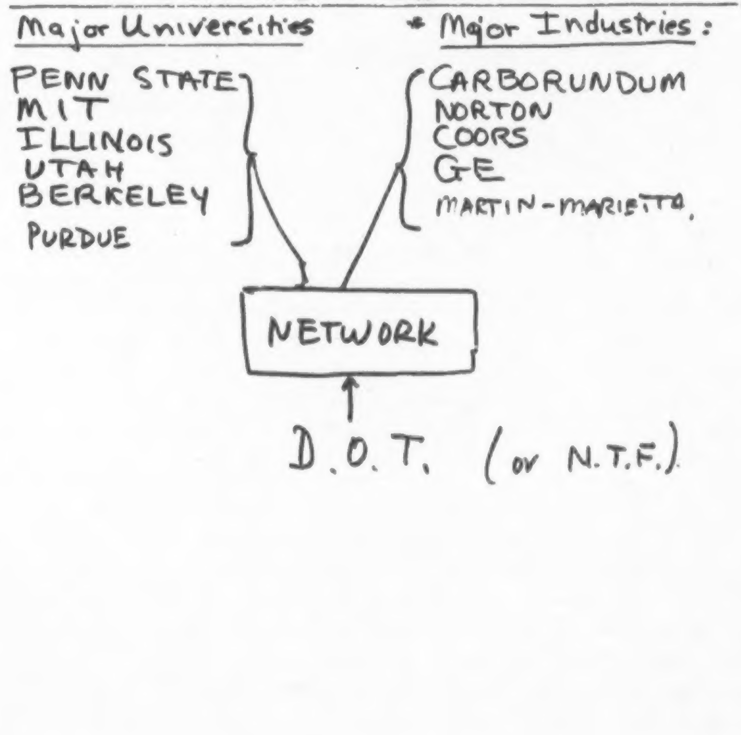

* Major Universities

PENN STATE
MIT
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UTAH
BERKELEY
PURDUE

* Major Industries:

CARBORUNDUM
NORTON
COORS
GE
MARTIN-MARIETTA.

NETWORK

D.O.T. (or N.T.F.)

Mr. GLICKMAN. The fact that you did not include schools like the University of Kansas doesn't mean that they aren't major universities. [Laughter.]

Dr. ROY. My definition here was ceramic materials and cement and concrete. [Laughter.] I ran out of ink.

Mr. GLICKMAN. You sound like a pretty good politician, too.

Thank you very much for your testimony. Dr. Kelly, why don't you proceed.

Dr. KELLY. Thank you, sir. It is a great honor and a privilege for an Englishman to appear before this distinguished and important committee, and I appreciate the invitation.

Mr. GLICKMAN. It is good to have you here.

Dr. KELLY. Thank you.

My name is Anthony Kelly. I am the vice chancellor of the University of Surrey. I have worked in materials research for the last 30 years. I am a fellow of the Royal Society. I have worked, and researched, in a number of countries, the United States, the United Kindom, Germany, and Switzerland.

I was until recently the chairman of the Materials Requirements Board of our Department of Industry, and I recently conducted an international study on the introduction of new materials. That will be published next month and I would like, if I may, to have it put into your Congressional Record because I believe it is germane to your deliberations.

If I could turn to the subject of new materials, new materials have extremely high gearing, so they take a long time to introduce. By high gearing, I mean that if you produce a new material successfully, then you often have a new industry. If you produce a single crystal blade, you can revolutionize an industry. Simple examples would be reinforced concrete revolutionizing road construction; liquid crystals recently revolutionizing display devices; the transistor is an obvious example. There has emerged recently the glass-reinforced cement industry, and there will be others.

The materials of construction are those which are widespread and energy cheap. It is not often recognized how the energy cheapness of cement and ceramic materials overrides that of all other materials, including metals and plastics.

My first slide demonstrates that, where I compare the energy to produce common materials. You will see that steel runs out at some 356 units per cubic meter, and cement only 29, an order of magnitude less. Other materials like glass run out at only 60, whereas aluminum, copper, and the plastics are very much greater. That means that the long-term future of these materials is good because the energy cost to produce them is very, very low indeed.

Further, as I said, the raw materials for such things are extremely widespread. There is no strategic problem with them. They have been underresearched, vastly underresearched, so that quite simple new techniques applied to them can produce striking new properties.

A particular example from an article I have just written for the Scientific American is shown on the next slide. It is obviously something of a tour de force, but you can make a spring out of cement material, so long as you have controlled the microstructure carefully and applied good science to a material like cement. The same will come about, I am quite sure, with other materials like cement, with the ceramics and materials, as I say, made of the natural oxides which are widely occurring.

I have little more to add, except to say that the comparative study to which I referred on the development of new materials shows the following features, and I would suspect that these are features which will be important for you in deciding your program of research in transportation.

The features to which I would draw attention are these—and they have been covered in part by one or two of the previous speakers. When developing new materials, as I said, they have very long leadtimes. You need to be steadfast; you need to spend the money over a long period. Carbon fibers, for instance, were invented in the 1960's, in this country, in Europe and Japan, simultaneously. They are only now, 20 years later, becoming a profitable commodity for the producers. They take long leadtimes, so you have to be steadfast.

Second, you must find a product champion, and you must reward that product champion if he succeeds. You often have to form cooperative ventures between suppliers and users. This may be driven by legislation or it may be driven by commercial considerations, but there are examples of transportation changes in our own country, for instance, the production of plastic car bumpers, where cooperative ventures between material suppliers and users have brought that about.

It is not solely a question of money. In my opinion, it's a question of networking existing strengths in any country, making use of the various types of expertise. In effect, where universities are concerned, in my opinion, putting the money where those universities can attract support from the relevant industries. In the United Kingdom at present we are moving toward that in a number of fields, in biotechnology, where I can give examples, or in the materials field in iron implantation techniques. We are moving toward the elimination of peer review in choosing research programs; rather networking with a lead lab and, where universities are concerned, supporting those universities which are working with industry. I think that is perhaps a pattern that emerges, not only in my own country, but also, from what little experience I have, from other countries. I think that is the way things are going.

That's all I have to say.

[The prepared statement of Dr. Kelly follows:]

TESTIMONY OF

Prof. A. Kelly
Vice-Chancellor, University of Surrey

Before The

Science and Technology Committee

of the

House of Representatives,

of the

U.S. Congress

June 15, 1983

NEW INORGANIC MATERIALS

by

A Kelly
Vice Chancellor's Office, University of Surrey
Guildford GU25XM, England

A note prepared for the Scientific & Technology Committee of the House of Representatives of the Congress of the United States of America to accompany a paper of the same title and a reprint from Scientific American Vol. 248, pp 104-115 (1983)

Summary

The thrust of the argument in this paper is as follows:

(1) Inorganic non-metallic solids have many useful engineering properties - listed in Section 1.

(2) The energy required to produce them is very small - section 2.

(3) They lack formability and things like quality pottery, china and electrical ceramics are made by high temperature routes - section 3 - and then the energy to produce them becomes large.

(4) They lack toughness.

(5) If inorganic non-metallic bodies (ceramics) were made by low temperature routes the low energy cost would be preserved. a number of possible low temperature routes are reviewed - sections 4 to 8.

(6) Some of the known methods of providing toughness in solids, made predominantly of brittle materials, are reviewed so that the quantitative limits to the toughness so far obtained are exposed - sections 9 to 13.

The new inorganic materials which are emerging are made from very cheap raw materials and in chemical composition they may be identical with the cheap constructional materials used today. However, I think that the initial markets for them will be in high added value products, eg replacing ceramic insulators or fine china, and such-like things and not in civil engineering and construction.

an Article from SCIENTIFIC AMERICAN

MAY, 1983 VOL. 248, NO. 5

New Inorganic Materials

Synthetic organic materials have come to play a key role in modern civilization, but unusual materials made out of sand, clay and other minerals have the advantage of requiring a smaller input of energy

by J. D. Birchall and Anthony Kelly

Look around you and you are likely to see things made of a wealth of diverse materials: metals, plastics, ceramics, glass and concrete. They are the stuff of a technological society. It takes energy to make them. In fact, the worldwide production of materials for construction and manufacturing annually calls for the equivalent in energy of 10^9 tons of oil, or 15 percent of the total worldwide expenditure of energy. The amount is equal to the total worldwide expenditure of natural gas.

The amount of energy required to make a material varies greatly from one material to another. It is useful to take portland cement as a standard, because it is made from chalk and clay, two readily available constituents of the crust of the earth. Moreover, portland cement is produced on a huge scale: almost 10^9 tons per year worldwide. It takes about 3×10^{10} joules of energy to make a cubic meter of portland cement. It takes six times as much to make a cubic meter of polystyrene plastic and 29 times as much to make a cubic meter of stainless steel.

Plainly portland cement, an inorganic material, has a considerable advantage in energy over plastics, which are made from organic material, and metals, which are smelted by processes that require very high temperature. This advantage, together with the wide and ready availability of the earth chemicals (the oxides of silicon and aluminum, the carbonates of calcium and magnesium and so on), suggests that technology should reexamine inorganic materials as replacements for energy-expensive materials, particularly at a time when energy itself is expensive and an end can be seen to the ready availability of hydrocarbons in the form of oil. Research we shall describe in this article is demonstrating that inorganic materials can in many applications indeed supersede the energy-expensive materials of present-day technology.

The first materials employed by human beings were flint and other kinds of stone, along with materials of animal or vegetable origin such as skin, bone and wood. Together they enabled human beings to excel at hunting and food gathering. Flint is hard, brittle and amorphous in its microscopic structure; thus it fractures conchoidally and can be fashioned into a sharp cutting edge. The Stone Age use of flint grew to such a scale that flint had to be mined rather than searched for in surface deposits.

The next material was bronze, which must have arisen from the chance juxtaposition of easily smeltable rocks (ores of copper and zinc) with sources of heat and with carbon. At much the same time it was discovered that wet clay would harden when it was baked and that before the baking it could be molded into a useful shape. Somewhat later came the reduction of iron ore into metallic iron. The earliest synthetic-material technologies, then, were metallurgy and ceramics.

A much later advance was the discovery, by the Romans, that a mixture of volcanic ash and lime reacts with water to form a hard, solid mass: a cement. This was the first low-temperature inorganic technology. In the reaction the silica (SiO_2) in the ash combines with the lime ($Ca(OH)_2$) to form a calcium silicate that has no regular chemical composition. In 1824 Joseph Aspdin improved on the technology by heating lime with a material such as clay, which contains silica. The result, after cooling, is portland cement clinker, which includes the silicates $2CaO \cdot SiO_2$ and $3CaO \cdot SiO_2$. When the clinker is mixed with water, it sets to a hard, firm, rocklike solid. Instead of shaping rock by chipping or cutting, civilization could now cast or mold it into the familiar form of concrete (cement mixed with sand and stone).

Metals, ceramics, rock and cement continued to dominate technology until the early years of this century. Cement, however, served only in low-grade applications. Then came the age of plastics, which can be said to have begun in 1907, when Leo H. Baekeland produced the first synthetic resin, Bakelite. Even before that, some natural polymers had been modified into materials with novel and useful properties. Natural rubber, for example, stretches when it is pulled. In 1839 Charles Goodyear found that the addition of sulfur stiffens it. The sulfur atoms form bridges between the hydrocarbon chains of which the rubber is composed. Nitrocellulose, developed by Christian Friedrich Schonbein in 1845, is brittle. In 1864 Alexander Parke discovered that the addition of camphor, a gummy substance from the camphor tree, makes it pliable. The camphor molecules act as a lubricant between hydrocarbon chains. The plasticized nitrocellulose served as the first motion-picture film.

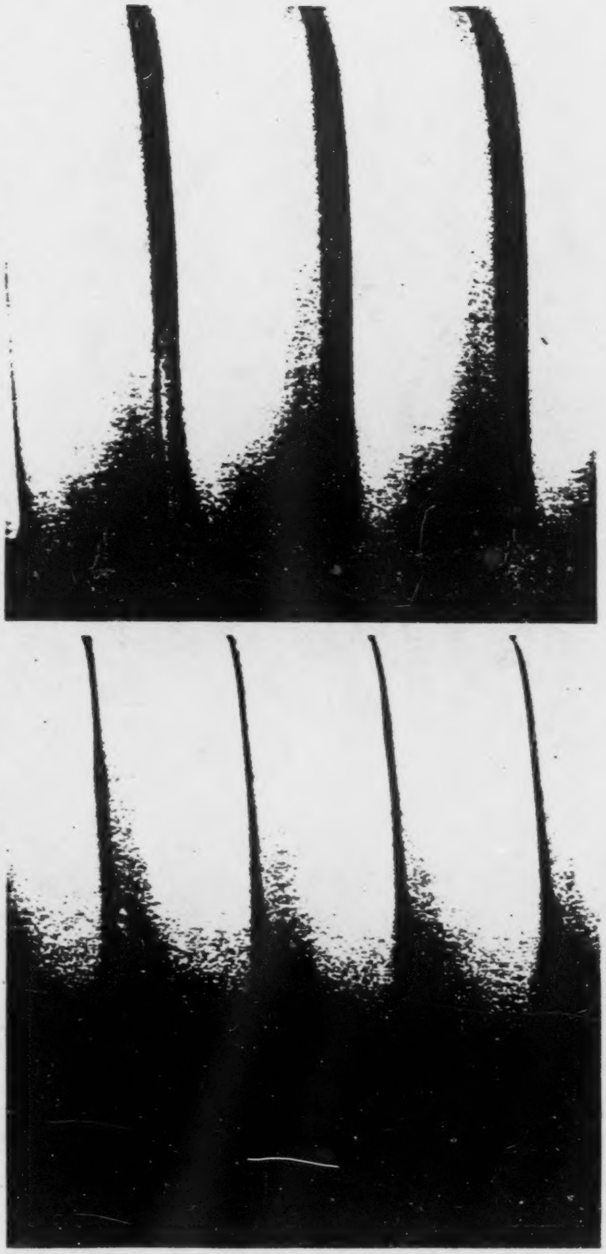
In the wake of Bakelite the age of plastics began in earnest. Synthetic rubber appeared in 1910, polystyrene in 1925 and nylon, polyethylene and polyesters in the 1930's. By 1940 the synthetic-polymer industry was well established. In that year the raw material for some 95 percent of all synthetic organic chemicals was coal. Today, four decades later, when the production of synthetic organic chemicals has increased more than a hundredfold, the raw material for some 97 percent is petroleum. Although the price of petroleum is currently decreasing somewhat, over the past eight years it has increased some fifteenfold.

What is the future for materials technology? One prospect is to derive synthetic polymers from coal once again. Surely that will happen. Another prospect is that the earth chemicals will again become prominent as raw materials. Apart from their availability, inorganic solids are intrinsically much stiffer than organic polymers. Moreover, concern is growing about the fire hazard of organic materials in homes and public buildings. Inorganic materials do not burn.

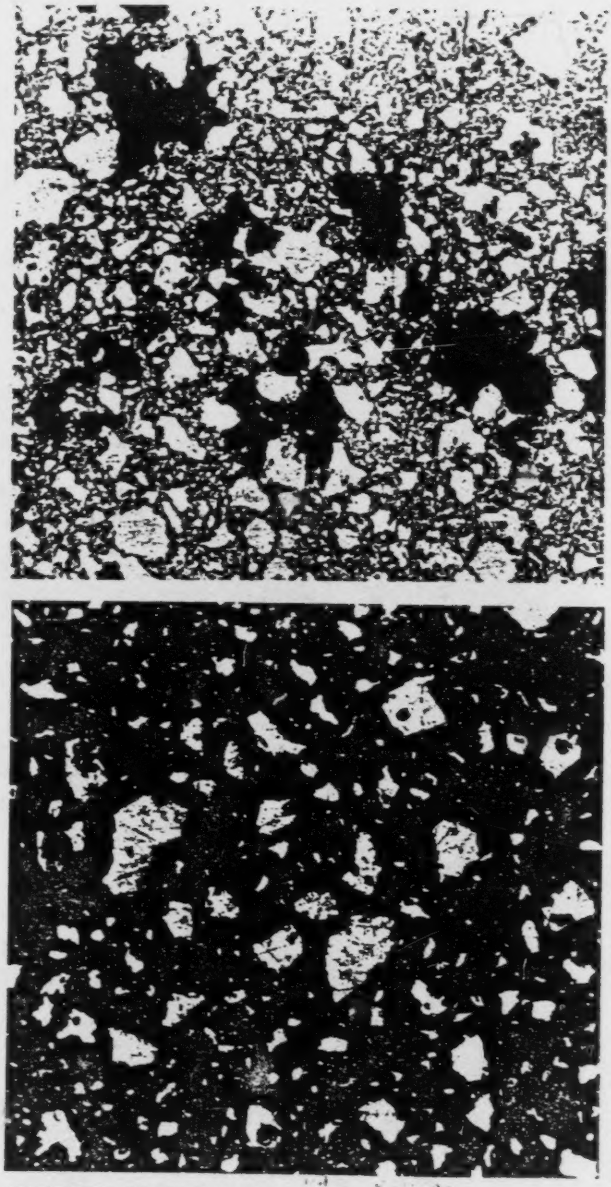
In the 1960's it was hoped that inorganic polymers would be synthesized in great variety and would find commercial application. Each inorganic polymer would be analogous to the organic polymers in being a long chain of repeating monomers, but the backbone of the chain would consist of atoms other than carbon. To date the only successful synthetic inorganic polymer that has emerged is silicone. In silicone the backbone consists of silicon atoms and oxygen atoms in alternation. Hence synthetic inorganic polymers have largely remained a dream. On the other hand, inorganic polymers taken fairly directly from nature are very widely used indeed; an example is glass. Moreover, the silicate rocks of the earth's crust consist of both chains and rings of silicon atoms and oxygen atoms in alternation. The problem is that the production of materials such as glass, as it is currently conceived, calls for high temperature, and high temperature defeats the objective of turning to inorganic materials in order to conserve energy.

There is a second problem. Consider the basic properties of materials that determine how the engineer incorporates them into a design. Three such properties are stiffness (the resistance of a material to bending), tensile strength (resistance to pulling) and fracture toughness (resistance to impact). They are properties any do-it-yourselfer would judge informally as he handled a material and decided whether or not to use it. Organic polymers and organic materials such as wood are not as stiff as inorganic materials such as ceramics and glass (one reason many synthetic organic materials are reinforced by incorporating into them fibers of inorganic material). The inorganic materials, however, lack toughness. If inorganic materials are to stand any chance of replacing plastics (and metals) in some applications, their toughness will have to be improved.

Can these two problems be solved? That is, can sufficiently tough inorganic materials be made at low temperature? The study of living organisms suggests they can. Living organisms exploit calcium carbonate, calcium phosphate and silica with remarkable control and sophistication. The abalone shell, for example, is 99 percent calcium carbonate; it is almost entirely chalk. Yet its tensile strength is more than 100 megapascals (14,500 pounds per square inch) and its



SPRING MADE OF CEMENT is shown under 300 pounds of tension (*top*) and under no tension (*bottom*). The cement is specially prepared to have no pores or other internal flaws larger than a few micrometers across. As a result the cement, which is called macro-defect-free, or MDF, cement, is highly resistant to fracture. Indeed, it is as strong as aluminum.



ABSENCE OF LARGE PORES in MDF cement is displayed in micrographs of a polished section of ordinary cement (*top*) and MDF cement (*bottom*). The pores in ordinary cement (*black patches*) can compose as much as 30 percent of the volume of the material. They are responsible for its lack of strength. The micrographs were made at an enlargement of 50 diameters.

toughness is more than 1,000 joules per square meter of new surface generated by fracturing, which makes it comparable in that respect to polystyrene and Plexiglas.

An examination of the shell's microscopic structure by means of electron microscopy shows how these properties are achieved. Flat plates of calcium carbonate, each about .2 micrometer thick, are stacked with impressive uniformity and are separated from each other by a thin layer of protein. A crack in the shell is thus forced to traverse a tortuous path and so the shell's fracture toughness is great. In a way that is not yet understood the protein serves the abalone as a template for the deposition of an ordered pattern of inorganic material at the temperature of the environment. The same is true of the growth of bone.

Let us examine in detail how a man-made inorganic material, say the ceramic porcelain, is created. The contrast with how the abalone fashions its shell is instructive. The basic process of making porcelain was discovered in China and was brought to the West in the early 18th century by Father F. X. d'Entrecolles, in what was probably the first recorded instance of industrial espionage. d'Entrecolles had spent time in Jingdezhen, a center of porcelain making in Jiangxi Province, and had learned Chinese in order to determine the role in porcelain making of the kind of clay the Chinese called kaolin. (To this day kaolin is one of the few Chinese words in the English language.)

High-quality ceramics such as porcelain are made by firing, that is, by heating to high temperature a mixture of quartz, feldspar and clays (usually kaolin and ball clay, a fine-grained clay that has some organic matter in it). To begin with, each of the powdered raw materials is mixed with water. The resulting pastes are pressed in a cloth to remove the excess water; then the pastes are combined and extruded through a screw under vacuum to remove most of the air in the mixture. The mixture is dried and shaped, much as a potter would shape it, and the resulting object is put into a gypsum mold to remove still more of the water in it. Next the object is coated with a glaze. The glaze is usually a clay combined with an additional flux: a material that readily fuses.

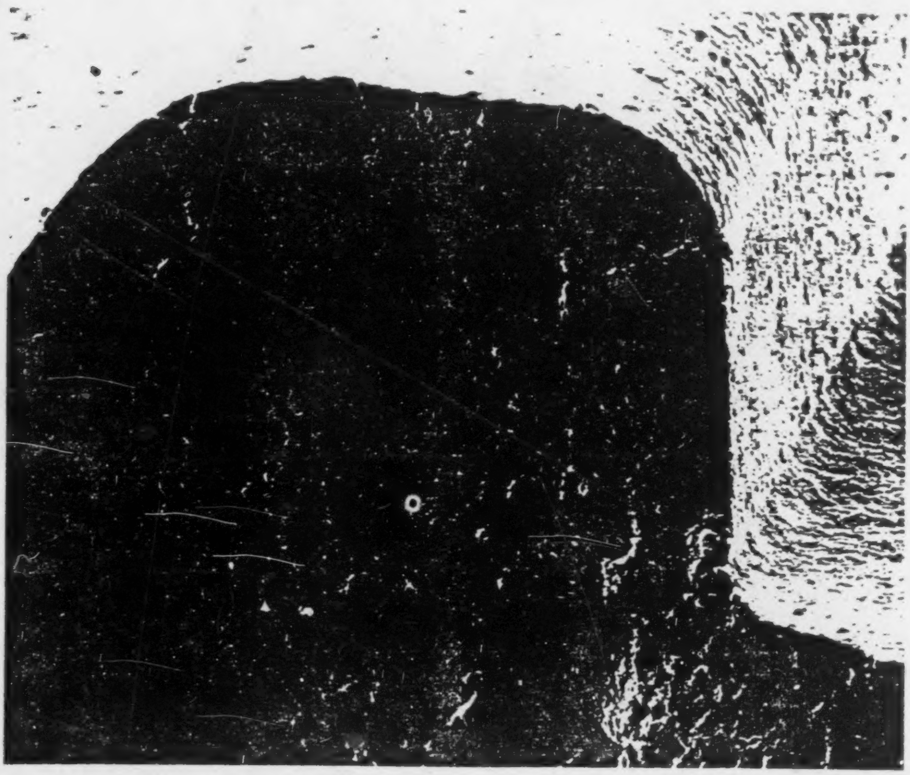
After further drying the object is fired. At temperatures of some 400 degrees Celsius a number of chemical reactions begin. Then at 600 degrees the material becomes glassy and crystals form in it, so that the material shrinks. The temperature is only about a third of the material's melting point, but that is deliberate: melting the material would give rise to large, irregular crystals rather than tiny, regular ones and in any case would require a large and costly expenditure of energy. On the other hand, atoms diffuse slowly in an unmelted material, so that when water evaporates, pores are left behind. Moreover, holes remain unfilled where clay particles fail to pack tightly. Further still, the individual crystals in the material are of varying composition and so are quite different in their mechanical properties. Notably they differ in their coefficient of thermal expansion: the degree to which heating makes them expand and cooling makes them contract. When the ceramic is cooled, therefore, some of the pores and holes may fill up but cracks and other blemishes develop. When the ceramic returns to room temperature, it is brittle and weak.

That is why all useful ceramic articles are coated with a glaze. The glaze is chosen to have a coefficient of expansion lower than that of the ceramic itself. Hence the cooling that follows the firing of the ceramic puts the glaze into compression. In effect the glaze holds the ceramic in a kind of vise, making it difficult for cracks to enter the ceramic from its surface and thereby lead to breakage.

Paradoxically, then, the high-temperature process of firing, which is intended to give the ceramic strength by allowing diffusion and shrinkage to fill up the gaps in the material, succeeds only at the expense of introducing cracks. High temperature, however, is not the only way to make atoms move so that they fill up gaps. Another way is to make water serve as a solvent for ions and as a medium for their diffusion. That is what happens in the hydraulic cements: solids that set and harden irreversibly in the presence of water. Gypsum is one example; portland cement is another.

When the calcium silicates in portland cement are mixed with water, some of the water takes part in the production of hydrated calcium silicates. Even today, 150 years after the invention of portland cement, the reactions are not well understood. The rest of the water is lost by evaporation, leaving pores in the cement. The pores vary in diameter from a few tens of angstrom units to more than a millimeter; together they can occupy 25 to 30 percent of the volume of the solid.

It has been known for many years that the strength of a cement, like the strength of a fired ceramic, depends on this porosity. The exact nature of the dependence has been elusive. First it was found that the strength of a cement depends on the ratio of water to solid when the cement is made. The strength increases as the proportion of water is reduced. Then it was proposed that the strength depends on the volume of the



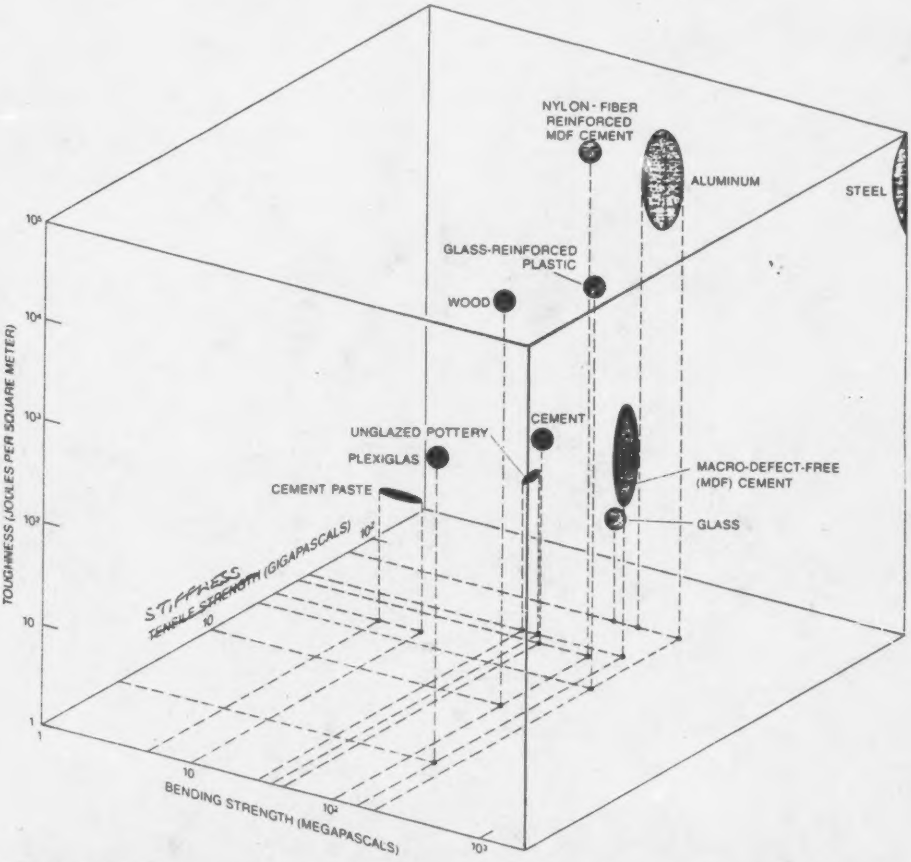
CEMENT BOTTLE CAP is an instance in which MDF cement replaces plastic. The cap has been fractured, and the fracture is shown crossing the thread of the cap in a scanning electron micrograph made at an enlargement of 75 diameters. The fracture is the dark area.

pores remaining in the cement after it has set. The strength increases as the porosity is reduced. The strength of a typical cement is actually rather low: its flexural strength is usually less than five megapascals and its tensile strength is only seven times higher. That is why cement and concrete are employed in construction only under compressive loads and why steel reinforcement is added when the material must bear a tensile load.

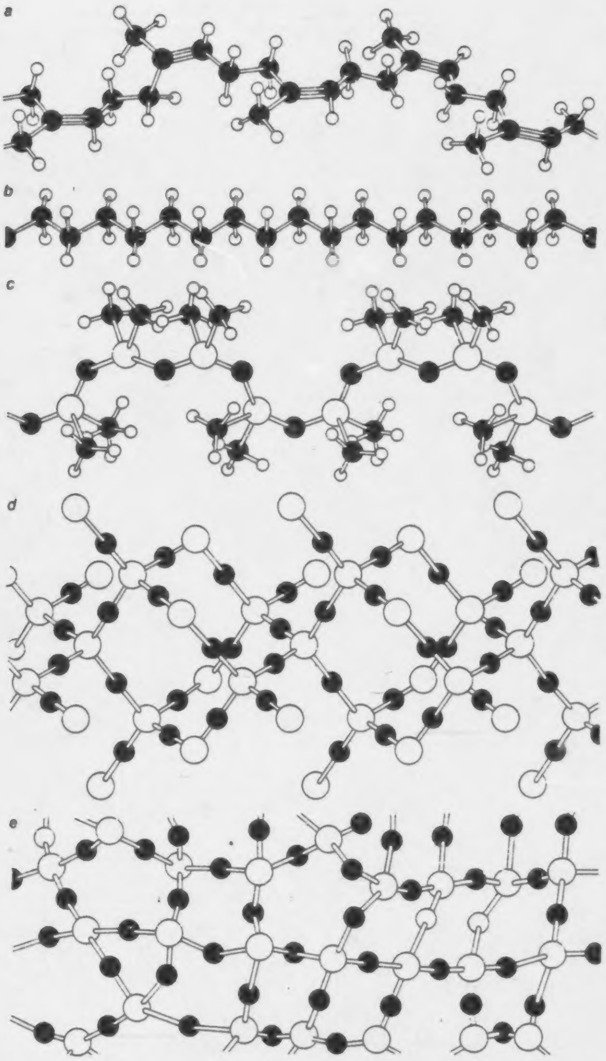
Suppose the relation between porosity and strength is extrapolated to predict the strength of a cement that has no pores. The result is a flexural strength of about 20 megapascals. The flexural strength of aluminum alloys is some five times as great, and the flexural strength of steel is 50 to 100 times as great. Even if the cement were reinforced with asbestos or glass fibers, one would predict a flexural strength of no more than 40 megapascals.

The extrapolation to zero porosity, however, is now known to be invalid. The simplest theory to explain the fracture of a brittle solid was developed in 1920 by Alan A. Griffith, who was then at the Royal Aircraft Establishment at Farnborough in England. He proposed that the tensile strength of a brittle solid is determined by the size of the largest flaw in the material. If the theory is correct, the strength of a cement should increase dramatically as the diameter of its largest pores is reduced. Conversely, the strength of the cement should depend only weakly on the number of pores or their volume.

That turns out to be the case. Anthony James Howard, Kevin Kendall and one of us (Birchall), working at the Imperial Chemical Industries (ICI) Research



THREE PROPERTIES of a material are its stiffness (resistance to bending), its tensile strength (resistance to pulling) and its fracture toughness (resistance to impact). Here the properties are plotted for various organic and inorganic materials. The scales are logarithmic. Organic materials such as wood rate high in toughness but low in stiffness. Inorganic materials such as glass are essentially the opposite. MDF cement rates almost as high as aluminum in all three properties. Stiffness and tensile strength are in pascals; one megapascal equals 145 pounds per square inch. Fracture toughness is the energy (in joules) that opens fractures adding up to one square meter of surface.



POLYMERS, long molecules made up of repeating chemical units, include a variety of useful materials, both organic and inorganic. Natural rubber (*a*), an organic polymer, tends to stretch when it is pulled. The addition of sulfur atoms makes it resistant to stretching by forming bridges between its hydrocarbon chains. Polyethylene (*b*) is a synthetic organic polymer. It was introduced in the 1930's and contributed to the growth of the plastics industry. Silicone (*c*) is synthetic and inorganic; its backbone consists not of carbon but of silicon and oxygen in alternation. It represents the only commercially successful synthesis of an inorganic polymer, yet such polymers are common in nature. The mineral cristobalite (*d*) is a polymer of silicon and oxygen, as is silicate glass (*e*).

Laboratories at Runcorn in England, have now shown that cement obeys Griffith's theory. Moreover, we have developed ways in which the maximum diameter of the pores in cement can be reduced from the usual millimeter or so to no more than a few micrometers. In essence the pores are kneaded out. In order to make the kneading thorough the cement grains are graded in size and a small quantity of a polymer is added as an aid to flow.

The new material has become known as macro-defect-free (MDF) cement. Tested in bending it shows a strength of more than 150 megapascals and in that respect is comparable to aluminum. Indeed, it is entirely possible to use cement to fabricate a spring.

The fracture toughness of MDF cement is also notable. Most common manmade inorganic materials have a fracture toughness of less than 10^2 joules per square meter of new surface generated by fracturing. In contrast the fracture toughness of wood is 10^4 joules per square meter across the grain. (It drops to 10^2 joules per square meter with the grain.) The mineral jade has a fracture toughness of 10^3 joules per square meter; that is why it can be carved delicately to shape. The fracture toughness of MDF cement is also about 10^3; on a conventional lathe, therefore, a block of it can be hollowed into a tube, a remarkable performance for an inorganic material.

Still, no cement is highly resistant to impact until it is reinforced with fibers. The technology of doing so has recently matured. In fact, strips of ordinary cement can now be made pliable. They can be bent like strips of metal. The bending does make cracks in the cement, but the cracks are quite narrow and the reinforcing fibers hold the cement together. Since the cement is made at low temperature, the fibers can be inexpensive organic ones that have a low melting point.

The new high-strength cement has the appearance of a ceramic; indeed, it would make good cups and saucers. It also has many of the characteristics of a ceramic. It is strong, hard, brittle and stiff, and it is formed largely by covalent chemical bonding. It is not, however, a refractory: a material that keeps its integrity at high temperature. The reason is that it contains water in chemical combination with its calcium silicates. At high temperature the water is driven off, leaving behind a much weaker solid. It would obviously be of value to devise methods of manufacturing refractory materials at low temperature.

Two approaches are promising. We noted above that the silicate rocks and minerals in the earth's crust are polymers in which alternating oxygen atoms and silicon atoms form chains and rings. In some of these minerals the chains and rings lie in silicate sheets some tens of angstroms thick. The sheets are separated from each other by layers of cations (positive ions) such as magnesium. One such mineral is vermiculite. George F. Walker of the Division of Applied Mineralogy of the Australian Commonwealth Scientific and Industrial Research Organization has discovered that the silicate sheets can be separated by removing or replacing the cations and then applying a shearing force. The result is a multitude of shards (fragments of the silicate sheets) thickly suspended in water. The suspension can be dried to make a strong, flexible, translucent and refractory film. Alternatively, the suspension can be whisked and then allowed to dry to make a refractory inorganic foam much like the organic polymer polystyrene. Here, then, is the complete re-creation of a natural mineral.

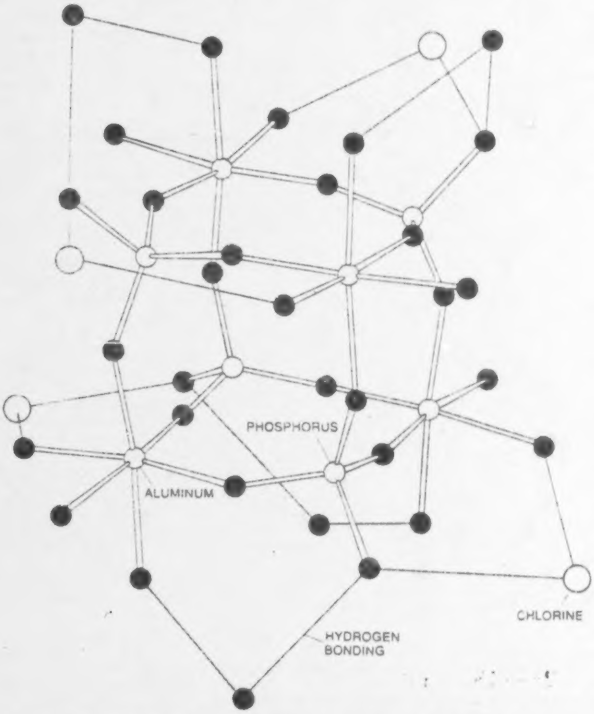
The second approach to the manufacture of refractory inorganic materials at low temperature is emerging from the study of solids such as glassy aluminum phosphate ($AlPO_4$). Aluminum phosphate is closely akin to silica, the archetypical inorganic refractory ceramic, and in fact it displays similar crystal forms. It is virtually impossible to produce glassy aluminum phosphate merely by melting the compound itself. The compound decomposes before it melts. On the other hand, a crystalline precipitate with the composition $AlPO_4 \cdot HCl \cdot (C_2H_5OH)_4$ can be prepared by reacting aluminum trichloride ($AlCl_3$) and phosphoric acid (H_3PO_4) in ethyl alcohol (C_2H_5OH) at temperatures lower than zero degrees C.

The structure of the precipitate is curious. It consists of aluminum, oxygen and phosphorus atoms in a cubic arrangement, but the cubes are prevented from linking by intervening molecules of ethyl alcohol. On gentle heating to about 100 degrees C. the alcohol is lost and the cubes do link. They form a three-dimensional lattice of aluminum, oxygen and phosphorus that is glassy and is refractory up to 1,600 degrees C., the temperature at which aluminum phosphate begins to decompose. The glass is inert and insoluble, but the precipitate from which the glass emerges is soluble both in water and in organic solvents. The precipitate can thus be dissolved and warmed. The process yields glassy coatings. Moreover, the precipitate can be used to bind together particles of compounds such as alumina (Al_2O_3) and so can serve the creation of a ceramic at a temperature of about 100 degrees C.

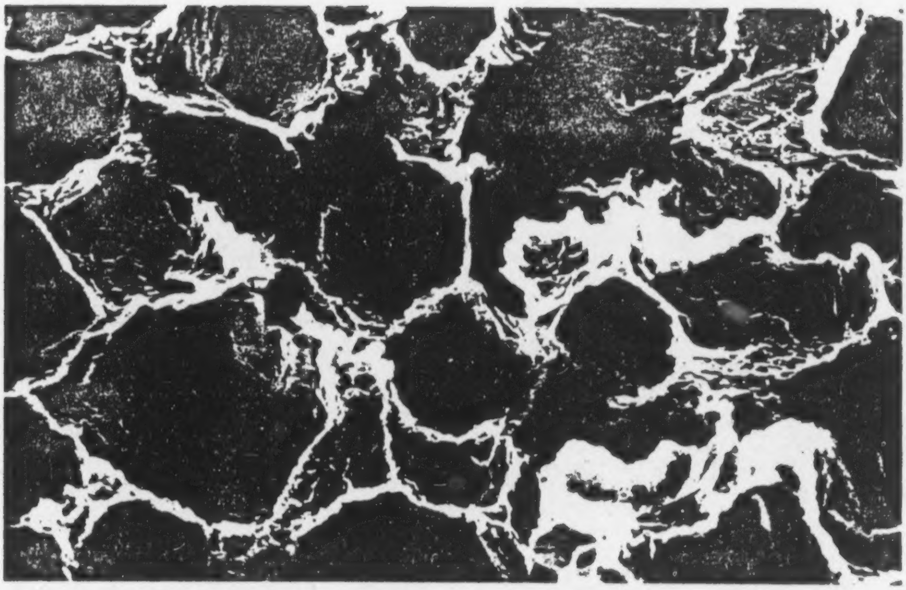
In related techniques developed by B. E. Yoldas of the Westinghouse Research Laboratories and by Masayuki Yamane and Tesuo Sakaino of the Tokyo Institute of Technology glasses are made at low temperature from alkoxides compounds that emerge from the reaction between an alcohol and an inorganic acid. Methyl alcohol (CH_3OH), for example, reacts with silicic acid ($Si(OH)_4$) to make silicon alkoxide ($Si(OCH_3)_4$) plus water. If the alkoxide is reacted with water, it is transformed into an oxide and an alcohol. The alcohol can be removed by gentle heating, leaving a glassy oxide behind. In principle the glass could be reinforced with organic fibers that have a low melting point, a strategy that is not possible in glass made conventionally at high temperature.

Like the cement described above, the glass produced at low temperature is porous. Here again, however, the pores are small, and so they have little effect on many physical properties. In making glass one often aims to control not only the mechanical properties of the material but also the optical properties. In particular the transparency of a glass requires that no pores be as large as a wavelength of the light the glass is intended to transmit. Many of the glasses produced by Yoldas are splendidly transparent: they contain no pores larger in diameter than 100 angstroms.

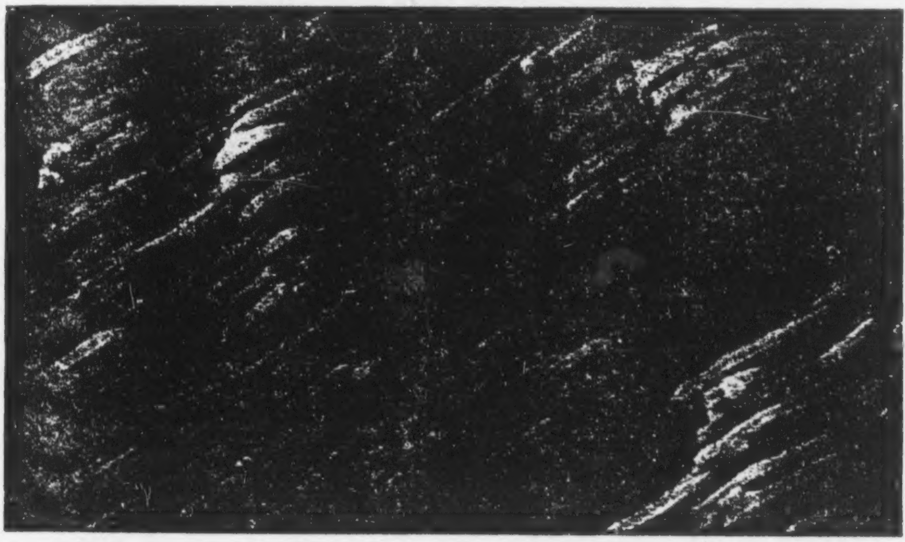
In the ways we have described, inorganic chemistry is preparing to contribute to the conservation of energy and of hydrocarbons by manipulating inorganic chemical compounds at low temperature. This manipulation is being aided by advances in the understanding of material properties such as porosity. Interestingly, the importance of the control of porosity had not emerged from all the previous work on high-temperature methods of fabrication. It may be too early to speak of a new Neolithic age, but its beginnings are clearly with us.



GLASSY ALUMINUM PHOSPHATE ($AlPO_4$) emerges from the reaction of aluminum trichloride ($AlCl_3$) with phosphoric acid (H_3PO_4) in ethyl alcohol (C_2H_5OH). The reaction itself yields the intermediate material shown here. Aluminum and phosphorus atoms form the vertexes of an approximate cube; oxygen atoms lie along its edges. The cubes are separated from one another by ethyl alcohol molecules. At a temperature of approximately 100 degrees Celsius the alcohol is lost and the cubes coalesce into a glass. The structure of the intermediate material was determined by John E. Cassidy and his colleagues at Imperial Chemical Industries.



FOAM MADE FROM VERMICULITE is a newly devised inorganic material that can supersede organic polymers such as polystyrene plastic. In vermiculite, silicate sheets are interleaved by layers of magnesium ions. The ions are removed and the sheets are sheared. The resulting slurry is whisked and dried to produce the foam. This scanning electron micrograph was made at an enlargement of 75 diameters.



ABALONE SHELL, seen in a scanning electron micrograph, is almost entirely chalk (calcium carbonate, or $CaCO_3$), yet it is stiffer than aluminum and as tough as Plexiglas. It confirms that inorganic materials can be designed to have new and useful properties. The shell consists of calcium carbonate plates that are .2 micrometer thick and are separated from each other by a thin layer of protein.

NEW INORGANIC MATERIALS

by

A Kelly

Vice Chancellor's Office, University of Surrey
Guildford GU25XM, England

A note prepared for the Congress of the United States.

Summary

The thrust of the argument in this paper is as follows:

(1) Inorganic non-metallic solids have many useful engineering properties - listed in Section 1.

(2) The energy required to produce them is very small - section 2.

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(5) If inorganic non-metallic bodies (ceramics) were made by low temperature routes the low energy cost would be preserved. a number of possible low temperature routes are reviewed - sections 4 to 8.

(6) Some of the known methods of providing toughness in solids, made predominantly of brittle materials, are reviewed so that the quantitative limits to the toughness so far obtained are exposed - sections 9 to 13.

The new inorganic materials which are emerging are made from very cheap raw materials and in chemical composition they may be identical with the cheap constructional materials used today. However, I think that the initial markets for them will be in high added value products, eg replacing ceramic insulators or fine china, and such-like things and not in civil engineering and construction.

NEW INORGANIC MATERIALS

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A Kelly

Vice Chancellor's Office, University of Surrey
Guildford GU25XM, England

1. Introduction

The view I take of cement and of its reinforcement is not that it is probably the cheapest constructional material but that it is one of the first synthetic, inorganic materials - based mainly on the oxides and silicates - that have an expanding future as engineering materials. This future is bright provided the brittle nature of these inorganics can be understood and controlled. Fibre reinforcement is one way of controlling the brittleness; there are others.

The inorganic solids of importance are principally the oxides and silicates. As a class these materials can be distinguished by the following physical properties:

- Densities lie in the range 2-4 X 10^3 kg/m^3.
- The elastic modulus can be very high, up to 300 GN/m^2. Even the lowest modulus, eg that shown by Portland Cement, at 20 GN/m^2, is much higher than that of the plastics.
- They are non-flammable, ultra-violet resistant and can be transparent.
- They are non-toxic if certain finely divided forms are avoided.

- They are usually available from very cheap and very abundant raw materials. They often form the waste products of large scale chemical and power producing processes.
- The energy required to produce them from raw materials is small.
- They have high melting points, and hence small coefficients of thermal expansion.
- They can be extremely strong in tension.
- The electrical conductivity can be varied over wide limits by control of the water content and/or the partial pressure of the surrounding oxygen.
- They are relatively resistant to damage by ionising radiations.

In competition with metals, the energy required to produce them is very much lower. They are available from very widely distributed and abundant raw materials. They have low densities. They can be just as strong as metals but not as tough.

In competition with plastics, they are non-toxic and non-flammable, resistant to ultra-violet radiation and very resistant to water penetration and consequent swelling. They do not provide environmental nuisance in waste form. They have much lower energies to produce them. They lack formability.

2. Energy Cost

Table 1 shows the energy requirements for the production of refractories compared with other materials. The range of energy costs for refractories and pottery are important. Cement has a very low energy cost because the production can be carried out on a very large scale and one single large-scale heating operation is required. I want to draw attention to the fact that, for refractories and pottery, the lower limits represent a very small energy cost in terms of GJ/m^3 but that the upper end of the range given leads to values exceeding the energy cost of metals and polymers. The upper end of the range in the production of high quality refractories and pottery is because of the enormous energy cost involved in ceramic firing processes.(1) The energy requirements for the production of these materials and hence the cost and simplicity of production could be much reduced if a high temperature stage could be avoided.

3. Production of a High Quality Ceramic

Consider the production of a high quality ceramic insulator made from a siliceous porcelain produced by firing a mixture of clays (Kaolin and ball clay) with feldspar and quartz (sand) - a rather higher strength can be produced by firing a mixture of clays, nepheline syenite (a pure sodium aluminium silicate with some potassium) and calcined bauxite (pure alumina). The production is shown in Figure 1. The essential raw materials are feldspar, kaolin, ball clay and sand, which are mixed in water. The water is pressed out by filtering through a cloth and the components mixed and screw extruded under vacuum to get rid of most of the air. They are then dried by an electric current and at this stage have some green strength; this varies greatly from 0.5 up to 8 MN/m^2 measured in flexure. They are then fashioned to shape as by a potter, often using gypsum moulds to remove some more water, then coated with a glaze (the glaze is essentially clay with additional flux) dried and fired at 1150°C. Ceramics for insulators are of the highest quality porcelain, as used in the finest tableware, and sell for one tenth the price. The glaze is important in determining the mechanical properties since it provides a smooth glossy surface of uniform colour and prevents pollution adhering readily to the smooth surface - the pollution is more easily removed. A glaze is used to increase the strength of the porcelain, and is selected so that, when fired, it has a lower thermal expansion than the body itself so that, in the firing process, the glaze is put into compression. The surface is thus in compression and the strength of the body increased. During the process of firing most of the advantage of the low energy cost of the ceramic raw materials is lost because of the energy expensive nature of the firing process.(1)

If it is intended to maximise the tensile strength there would be general agreement among all chemists that the porosity must be reduced as much as possible, the microstructure made as uniform as possible and internal cracks must be avoided. The pores are reduced in size when the glassy phase melts, and a sufficiently high temperature must be reached in order to achieve this; too long a period at high temperature leads to pore growth and a decrease in strength. Work over the last five years, but only recently published (25a), lays emphasis on the detection and elimination of the largest pore present in controlling the strength of a brittle inorganic (cement paste). The largest pore present controls the strength. A uniform distribution of pores of diameter up to, say, 100 nm in volume fractions of up to 10% will have no effect on strength up to strengths of ~ 2 GPa provided no larger defects are present. There is no reason in principle why control of the microstructure and elimination of large pores and defects cannot be carried out at low temperature, and if processing is possible without a high temperature stage then additives may be made which cannot be introduced if a high temperature stage is necessary.

4. Production of Inorganic Bodies by Low Temperature Routes

A summary of the basic ceramic fabrication processes is given in Table 2. Firing at high temperature is always involved. Sambell (2) has also considered more novel modern techniques*, all of which involve a high temperature process except possibly electrophoretic deposition. In view of the high energy cost of firing, we should concentrate our efforts on the production of inorganic bodies by processing routes which do not involve a high temperature. To be specific, let us make the upper limit of processing temperature say 300°C. Most inorganic materials - see Table 2 - are produced by a process of sintering or hot pressing of powder. The powders are usually produced at low temperatures but the sintering, despite the addition of fluxes, eg silicates to alumina to lower the temperature and pressures, requires a temperature well in excess of 300°C. This is so even for powders of small particle size if the body is to have acceptable values of porosity. Porosity decreases with higher sintering temperature.

The only process I know of for compacting a powder of a ceramic material without external heating to a high temperature is dynamic powder compaction(3). The process there described has been applied to metals but it is known that it can be applied to some ceramic bodies.

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* These are (a) vitreous phase sintering, reaction sintering, activated hot pressing, reaction hot pressing, pressure calcintering, chemical vapour deposition, polymeric precursor, pyrolysis, silicone precursor additive, which are thermo-dynamical methods; (b) injection moulding, isostatic pressing, ultrasonic hot pressing which are mechanical methods and (c) electrophoretic deposition.

What are the methods available for putative production at low temperatures? Vapour deposition and sputtering can, I think, be excluded at present although in both the solid may be formed at a low temperature. In the first a gaseous species must be decomposed. The temperature is usually greater than 300°C eg silica may be deposited from $SiCl_4$ and water decomposed at $> 900^{\circ}C$ and alumina from $AlCl_3$ carbon dioxide and water at $> 800^{\circ}C$; only thin films are usually produced. Sputtering is very expensive for any but the smallest quantities.

Thermal decomposition of a vapour or gas has often been used to make inorganics, particularly fibres, eg silicon carbide can be made by the reduction of methyl-trichlorsilane with hydrogen or by the reaction of silicon tetrachloride with acetylene or other alkenes or alkanes. None of these is accomplished at low temperature - see Kelly (4) for a review - nor is it for other inorganic materials of high melting temperature. Recently Yajima(5) has produced silicon carbide by a more complicated chemistry by the heat treatment of organo-silicon compounds in analogy with the formation of carbon fibres (a ceramic element?) by pyrolosis of an organic fibre . Since silicon carbide can be sintered only with great difficulty, Yajima's aim is the same as that described here, namely to obtain a fully dense silicon carbide at a relatively low temperature. However, temperatures of 1300°C are finally needed to produce the silicon carbide.

Considering other processes, we can consider first direct reaction. So far as I am aware, this usually involves an acid-base reaction if it is to proceed at a low temperature. One of the compounds involved usually needs to be in fluid form. An example would be the production of silicon phosphate,

$$SiO_2 + P_2O_5 \rightarrow SiO_2.P_2O_5 \quad (SiP_2O_7)$$

by the action of pyrophosphoric acid on silica, eg (6) at 300°C. Alternatively freshly precipitated silica may be dissolved in phosphoric acid at room temperature and on gentle heating crystals of composition $SiO_2.P_2O_5$ are deposited (7). The material is very stable with a melting temperature in excess of 1800°C and great stability to acids and alkalis; it is difficult to make other than by direct interaction of the constituents. Silicon phosphate is a crystalline network polymer in which every silicon atom is joined to six oxygen atoms and every phosphorous to four oxygen atoms.

Dental fillings are essentially ceramic materials produced by a low temperature route. Dental cements are quite different from cements used outside dentistry and conversely dental cements have not been adopted for uses outside dentistry. Unlike hydraulic cements, dental cements set as a result of an acid-base reaction between a powder and a liquid - viscous hydrogen bonded liquids, such as orthophosphoric acid, a poly-alkenoic acid (polyacrylic acid) or liquid organic chelating agents, such as 2-methoxyphenols (eugenol in particular). The cement-forming reaction for the whole range of dental cements can be described simply and generally (8) as

$$MO + H_2A = MA + H_2O$$

of if the powder is a silicate,

$$MO.SiO_2 + H_2A = MA + SiO_2 + H_2O,$$

where M represents the cation in the powder and A the anion in the liquid (both taken as divalent for convenience). MO or $MO.SiO_2$ represents the powder, H_2A the liquid and MA the salt-like cement product. Thus M can represent $Zn^{2+}Al^{3+}$ and A can represent phosphate, polyacrylate, eugenolate, etc. The products of the reaction are the cement, water and, in the case of silicate, silica-gel. The powders are usually amphoteric oxides, capable of acting as proton acceptors eg ZnO or alumino-silicate, ion leachable glasses, containing appreciable amounts of fluoride.

Zinc phosphate, zinc oxide eugenol and dental silicate cements (an alumino-silicate glass reacted with phosphoric acid) are traditional materials developed at the end of the 19th and early 20th centuries (see Wilson (8) and Wilson and Crisp (9)). The newer materials are the ionic polymer or ionomer cements in which an anionic polyelectroyte is used as the cement-forming liquid (eg polyacrylic acid) which is highly carboxylated so that the mole ratio C:COOH is about 3:1. This reacts with an alumino-silicate glass which has usually been made by fusing quartz, silica and alumina in a cryolite fluorite flux containing small quantities of phosphate (10). Under the electron microscope the structure of the conventional dental cement appears as a composite of eroded (partially reacted powder particles connected by a matrix). Dental cements are a sort of filled composite material, the matrix being formed from the reactants or alternatively the glass ionomer cements represent "a cold cured ceramic-organic polymer hybrid" (Wilson).

5. Preparation from Solution

Many ceramic materials, particularly the oxides, can be produced in a very wide range of powder forms directly from a solution. Newer methods involved the sol-gel process. Alumina, chalk and many other oxides may be made in this way. However, their compaction into a ceramic body always involves a high temperature firing process. In some cases, however, a solid can be produced directly from solution. For example, parallel fibres of silica can be produced by the directional freezing of aqueous polysilicic acid (11) and a variety of other shapes can be produced by control of heat transfer, diffusion kinetics and interfacial surface energy by appropriate additives. The fibres as produced are of composition $3\ SiO_2.H_2O$ and are porous with a surface area of $900\ m^2g^{-1}$. After heating at 925^oC for eight hours, the composition corresponds to SiO_2 and the density $2.20 \times 10^3 Kgm^{-3}$

corresponds to a porosity of 12%.

Monolithic silicate glasses and pieces of alumina and other oxides can be prepared by methods requiring a temperature of no more than 400°C to 500°C (nearly within our target temperature) by the careful heating of gels formed from metal alkoxides (29,30,31). An alkoxide such as $Si(OCH_3)_4$ diluted with alcohol can be hydrolysed by water to $Si(OH)_4$ at room temperature to form a gel and after drying of this gel a monolithic solid of composition $SiO_{1.50}(OH)_{0.96}(OCH_3)_{0.033}$ is obtained at room temperature with a density about 82% of that of pure silica (30) with a specific surface area of about 600 m^2g^{-1}. Metal organic compounds, where an organic is linked to a metal via oxygen can be made of almost all metals and the metals mixed at the molecular level. The alkoxides are most important and hydrolysis leads to the formation of the oxide. To produce the pure mixed oxide without water or the remains of organic requires heating to 400-500°C and the resulting monoliths are always porous up to 20% by volume. However, the pores can be very small ($<$ 100 nm in diameter) and uniform and so the resulting solids are quite transparent - Figure 4.

Sometimes a fully dense film can be prepared directly from solution. For example, pure aluminium phosphate $AlPO_4$ - an excellent binder of refractories and useful as an impervious glassy film in its own right, which has a melting temperature of greater than 1500°C - can be prepared at less than 50°C. Aluminium trichloride and phosphoric acid are allowed to react in ethanol and crystals of a complex aluminium chlorophosphate-ethanolate separate out. Best yields are obtained if the reaction is carried out at or below 0°C and if equimolar quantities of aluminium trichloride and phosphoric acid are used and water rigorously excluded from the system. The complex decomposes to $AlPO_4$ (12)

$$AlPO_4.HCl.4C_2H_5OH \longrightarrow \underset{\text{glass}}{AlPO_4} + HCl + 4C_2H_5OH.$$

This material is interesting since $AlPO_4$ is isostructural with silica SiO_2 ($SiSiO_4$) so that similar polymorphs are found. $AlPO_4$ cannot be melted to form a film.

6. Composite Materials

The ionic polymer cements referred to above are a product of the hardening reaction that occurs when aqueous solutions of highly carboxylated acid polyelectrolytes, in particular polyacrylic acid, are brought into intimate contact with certain simple or complex metallic oxides. The oxides are a source of cations, eg Ca^{++} or Al^{3+} which serve to ionically cross-link the polyionic chains to form a hard gel or glassy matrix in which the oxides are contained. Since the gel-like matrix contains much organic polymer in the form of a linear covalent chain, the ionic polymer cements are a sort of intermediate between a filled organic polymer and an inorganic cement.

Filled thermoplastics are made by tumble mixing powders of polymer and the required filler. Sometimes the polymer may be melted. Mineral oil or glycol is added as a wetting agent and surface treatment of the filler with coupling agents such as silicones or stearates is regarded as essential (13). The volume fraction of filler rarely exceed 0.3. It is not widely known that packing fractions of solids up to 0.95 can be obtained by using a mixture of spheres with diameters in the ratios 1:3:9:17 in the proportions of 40:10:10:40 per cent respectively by volume. Such mixtures of solid particles also flow easily (14,15).

By dispersing a polymer in fluid form in such an array of solids, a very highly filled polymer can be produced which will, of course, have properties resembling those of the filler. Some of the newer dental cements are in effect a dispersion of silica sand in a polymer chosen for its desirable light-curing characteristics. Fotofil consists of a very high volume fraction (up to 70%) of glass; either quartz glass or borosilicate with the borosilicate containing some barium to make it radio opaque. The high fraction of filler is achieved by using particles of a variety of sizes with a silane coating to promote bonding to the resin (a vinylurethane, arranged to be light-cured in the blue end of the spectrum). The resin and filler have matching refractive indices and the two fillers are adjusted to obtain the correct translucency and opacity. The flexural strength is 120 MN/m^2 and the compressive strength 280 MN/m^2. In effect a porcelain has been made without a high temperature stage and of adequate strength and water resistance without use of a glaze (16).

Similarly, adequate substitutes for sanitaryware ceramics can be made by producing very highly filled polymers containing 72% by weight or 55% by volume of silica sand dispersed in methyl-methacrylate. Again an adequate volume fraction is obtained by paying attention to the range of particle sizes of the sand and the rheology of the polymer coupling agent.

The method requiring the least energy and the most logical for the production of a ceramic material would be to take the raw material, disperse it into component particles and then reconstruct the required object. This is, in effect, what occurs with the processing of asbestos.+ Rock is broken up by crushing, washing in water and then hammer milling. Asbestos paper is made by dispersion in water followed by filtering away the water. The binding between individual asbestos crystals is not high and asbestos paper is weak. Since the form of the crystals is fibrous, ropes may be, of course, produced. However, the simplest board products made of asbestos contain the individual crystals, cemented together with a cheap binder such as sodium silicate, and there are other simple examples, such as the making of bricks from pulverised fuel ash - usually cenospheres - again bound together with sodium silicate.

There is a most important extension of this which Ray (1978)

+ Chipboard could be another example

calls reconstructive processing in which a naturally occurring mineral is dissected by chemical methods into small geometrically similar fragments.* The fragments can be, and often are, of colloidal dimensions. These fragments are then reassembled into the required shape. Clay minerals such as vermiculite can be dispersed in water by shearing forces in a mill after exchange of the interlayer magnesium cations by, for example, n-butyl ammonium (19,20)+. The butyl ammonium causes the material to swell after which it is easily broken up by shearing forces. An aqueous suspension of plates is obtained, one or two silicate layers thick and some tens of micrometers in planar dimension. By evaporation at low temperature, coherent layers of these

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* It may be essential to use chemical methods since there is apparently a lower limiting size of particle to which a material may be reduced by comminution or crushing. This lower limit is about $10\,E\gamma/\sigma_y^2$ where E = Young's modulus, γ the work of fracture and σ_y the yield stress in compression (17,18). For a material with $E = 100\ \mathrm{GNm^{-2}}$, $\gamma = 1\ \mathrm{Jm^{-2}}$ and $\sigma_y = 100\ \mathrm{MNm^{-2}}$ this size is about 100 μm. A general expression for this lower limiting size can be found by noting that for brittle materials γ will be of the same order of magnitude as the surface energy and hence,

$$\gamma \approx \frac{E\,a_o}{10},$$

where a_o is the lattice parameter. The lower limiting size of particle produced by comminution or crushing, a, is then

$$a \approx \left(\frac{E}{\sigma_y}\right)^2 a_o$$

whence $a_o \approx 2 \times 10^5 a_o$ for $\left(\frac{\sigma_y}{E}\right) \sim 2 \times 10^{-3}$

+ See Flexible Inorganic Films and Coatings. D G H Ballard and G R Rideal, J Mater Sci, 18, 545-561 (1983) suspensions can be obtained and these may be either used as they are, when the electrostatic forces between platelets bind them together, or else magnesium or other ions may be reintroduced in order to increase the binding. Bulk materials may be made by deposition of successive layers. Such reconstructed dispersions contain few voids and the void content can be controlled.

Other layer structures might be processed in this way, particularly if they could be dispersed by chemical methods and where this is not possible perhaps by electro-hydraulic processing which can be applied to mica. Many layer minerals, particularly micaceous ones, can be decomposed into flakes by heating but this method may require large energy, of course.

7. Cements

Inorganic materials can be produced by through-solution methods involving gel formation or precipitate formation in water. The most widely used inorganic produced by a low temperature route and having the potential to rival metals and ceramics in its mechanical properties is cement. There are many cementation reactions in which a solid and a fluid react to give a solid. An early one is Franceso Lana's chemical miracle of 1686 - see Partington (1947)(21) in which saturated solutions of calcium chloride and sodium hydroxide when mixed produce a solid

$$CaC\ell_2 + 2NaOH = Ca(OH)_2 + 2NaC\ell$$

and the water all disappears!.

Almost any salt which can contain water of crystallisation, if de-hydrated and subsequently mixed with water, will shown a cementation reaction. Only in some will the resulting solid be insoluble in water, eg many of the alkaline earth silicates and aluminates or mixtures of metal oxides with the corresponding metal chloride or sulphate. Composition diagrams giving the approximate chemical composition of commercial cements are shown in Figs 2a and b (22). The most widely used is Portland Cement which consists of anhydrous crystalline calcium silicates, the major constituents being tricalcium silicate, $3CaO.SiO_2$ and beta-dicalcium silicate, $2CaO.SiO_2$ approximately in the ratio 2:1. When anhydrous cement is mixed with water the calcium silicates react to form hydrates and $Ca(OH)_2$. Hardened Portland Cement paste consists roughly of 70% of calcium hydroxide together with unhydrated calcium silicate particles and some calcium aluminate, ferrites, calcium oxide, etc. In the set cement porosities of 20-30% are common. Observation of the cementation reaction in a high voltage electron microscope (23) and chemical evidence (24) shows that it is essentially a two-stage process in which a gelatinous layer is initially formed on the surface of the calcium silicate particles. After about two hours this gel layer sprouts fibrillar outgrowths which may actually be tubes. The fibrils rapidly increase in length and number and become enmeshed. During the process, calcium ions from the calcium silicate particles are slowly dissolving leading to the formation of calcium hydroxide. Eventually one obtains a dense mixture of calcium hydroxide crystals, hydrated silica gel and unreacted "cement" grains. The material has a very high surface area (200-300 m^2g^{-1}) indicating a high porosity and if no attempt is made to control this, the material is very weak in tension - an upper limit being apparently set by the porous structure of 15 MN m^{-2} (25). Under these conditions, the strength of the material is notch-sensitive; its strength is governed by its (porous) micro-structure, being hardly affected by external flaws. Control of the porosity can lead to large increases in strength (25a), eg up to 70 MN m^{-2}.

8. Biological Methods

Strong inorganic materials are assembled by low temperature methods in several natural processes when load bearing and protective tissue is made. The methods are slow but until the process of biological deposition is well understood, it cannot be assumed that a rapid method of growth may not be attainable. The properties of mollusc shells, mother-of-pearl (nacre) and antlers (bois de cerf) are interesting. For instance, Currey (26) has measured the mechanical properties of mother-of-pearl in tension. This material consists of plates of aragonite ($CaCO_3$) about 0.3 μm thick arranged in sheets within a tenuous protein matrix. The Young's modulus is up to 50 GN/m^2 and may be greater than this and the tensile strength can be 110 MN/m^2. Importantly, the fracture energy can be up to 3,000 J/m^2. Molluscs have a variety of structural arrangements of the material of their cells (27). The material is calcium carbonate in the form of either aragonite or calcite and the volume fraction of the organic is given variously between 1% and 6% (28). Nacre is produced by three molluscan classes - bivalvia, gastropoda and cephalopoda. There are several crystallographic orientations of laminar crystals which contribute to the fracture toughness. We do not know how the calcium carbonate and pH levels are regulated or how the protein content of the fluid which secretes the aragonite crystal relates to the shell composition. However, it is known that the normal methods of crystal growth occur since screw dislocations are observed in the growing aragonite crystals.

9. Toughness

Incorporation of fibres into cements and other brittle materials enables these to be used in tension and the principles governing the load extension curves, in pure tension and in bending as well as the hysterisis effects are well understood (32,33,34,35,36). It does not matter whether the matrix is a glass, Portland Cement or a ceramic - the behaviour is the same though great attention must be paid to relative coefficients of thermal expansion if a high temperature is used to fabricate the composite as has often been the case with ceramic matrices containing metal wires in the past. When fibres are successfully incorporated the stress strain curves obtained in tension are of the form shown in Figs 3a and b. If no fibres had been present failure would have occurred at strains of about 0.02%. Clearly the area under the stress strain curve which is a measure of the work of fracture is very greatly increased when fibres have been incorporated. However discussions of the advantages of fibre reinforced cement usually pay rather little attention to the values obtained of the work of fracture. The increase in toughness obtained by introducing fibres is enormous, eg in an impact test the work of fracture is increased from $15 J/m^2$ to several thousand J/m^2 (36). This has usually been measured in a Charpy or Izod test. For the application of inorganics to situations where these compete with metals and plastics, quantitative discussion of the values obtainable is important.

Metals and wood are tough in two distinguishable senses:

1. If given a large blow of energy, say in a Charpy or Izod test, much greater than that required to break the piece, then a tough material requires a considerable energy to be expended on the material in breaking it into two pieces, eg for stainless steel $5 \times 10^4 J/m^2$ and for teak wood $6 \times 10^3 J/m^2$. Adequate

resistance to such a blow is impact toughness. It is usually provided for in fibrous brittle systems by the provision of weak interfaces which allow the matrix to split and so effectively remove any sharp crack running normal to a set of fibres. Cracks usually run easily parallel to the fibres, however.

2. If a sharp ended fillet or cut is made in the piece or introduced adventitiously, then if the material is tough, this will not extend under a stress until that stress is closely equal to the breaking stress of an unnotched sample. Such toughness is notched toughness. Obviously, failure in this second mode depends on the depth of the sharp ended cut and materials designed for use at high stresses must possess large values of toughness.
3. There is also a subset of 1. in which a projectile of very high energy strikes a material eg a bullet striking bullet resistant glass. The measures of performance here are all empirical. Brittle materials can be very effective provided they are linked by multiple interfaces.

Works of fracture greater than $10^3 J/m^2$ are all produced by some irreversible sliding mechanism since equilibrium surface energies are in the range $1-10Jm^{-2}$. In metals the sliding mechanism is plastic flow, ie by motion of crystal dislocations. In fibre composite materials various contributions have been stated as contributing to fracture toughness. These are pull-out - which includes sliding at the fibre matrix interface such as occurs during multiple fracture of brittle matrix composites; debonding at the fibre matrix interface; de-lamination - which usually means splitting parallel to the interface between laminations; and multiple fracture of matrix - that is, cracking of the matrix perpendicular to the fibres. The relative contributions of these have been considered for glass reinforced plastics by Harris, Morley and Phillips (38). All brittle systems, (ie fibre and matrix both brittle) have been considered by Aveston (37) and by Phillips (39). The values of toughness depend on the specimen shape and method of testing. There is little uniformity. The relations between some of the methods has been discussed in an illuminating fashion by Phillips and Harris (40).

In all cases the predominant contribution to toughness in fibre reinforced systems is made by the work of pull-out. Its contribution varies as

$$W_{po} \propto V_f \sigma_{uf} \ell \qquad (1)$$

ℓ is the length of pull-out and σ_{uf} the breaking strength of the fibres. ℓ is determined by the geometry of the test, the arrangement of the fibres and its precise definition can involve a description of the mode of failure. ℓ is controlled by the fibre-matrix interfacial shear strength (not the so-called interlaminar shear strength) being larger for smaller values of τ. The largest length of pull-out of a cylindrical fibre of diameter d is given by

$$\frac{\ell_c}{d} = \frac{\sigma_{uf}}{2\tau} \qquad (2)$$

If τ is made too small, the shear strength of the specimen itself may be too small (39). The incorporation of fibres which may be either brittle themselves, eg glass, or quite tough, eg nylon or steel, can provide toughness without any doubt. The incorporation of silicon carbide fibres into a glass ceramic can provide a work of fracture of 20 x $10^3 J/m^2$ (37). This seems to be the largest value so far obtained. Glass fibres in cement can produce a material with the work of fracture of the same order as can polypropylene cement with only 5% of polypropylene (36). These measures have been obtained essentially in impact tests when a specimen is bent to failure by a sudden blow.

It is also important to know whether fibres incorporated into a brittle material can provide notched toughness. Here again pull-out appears to be the cause of the dissipation of energy and the point has been explored by Phillips (39) who put carbon fibres into a brittle glass. Both materials were brittle and the notched toughness observed was 6 x $10^3 J/m^2$, and this was the same value as was obtained by impact measures or slow bending to failure. The values of the notched toughness measured by the value K_c are up to 20 $MN/m^{3/2}$. The largest value obtained has been given by Prewo and Brennan (41) and is 18 $MN/m^{3/2}$. This value is rather small compared with the values of the plane strain fracture toughness of high strength steels where at comparable values of the yield strength (up to 1 GN/m^2) the values are usually 100 $MN/m^{3/2}$[†].

The provision, by incorporation of fibres, of impact toughness appears to be understood in terms of pull-out and it does not matter whether the fibres are stiffer than the matrix or not. It is known that fibres can provide notch toughness but the conditions under which this is obtained are by no means so well understood and in particular it is not known whether notched toughness can be obtained with small volume loadings of fibres of elastic modulus less than that of the matrix. If this is so, it has not been demonstrated experimentally.

The biological materials mentioned above can show values of the impact toughness of up to $3 \times 10^3 J/m^2$. These values are found in naturally occurring pieces and there is no doubt that larger values could be obtained if attention were paid to increasing the toughness. It is apparently due to crack deflection since the essentially laminar microstructure is arranged in different orientations in different parts of a mollusc shell and there is no doubt that there is some deformation of the (unknown) protein which lies between the plates of aragonite. However, we can only look on these materials as providing promise without there giving us quantitative guidance on what might be obtained.

[†] Wood (spruce across the grain) gives values up to 7 $MN/m^{-3/2}$ (47) and works of fracture of $7.3 \times 10^3 Jm^{-2}$ but of course with very much lower values of the Young's modulus ($\lesssim 10 GN/m^{-2}$)

10. Plastic Flow between Hard Particles

Whether toughness of adequate amount can be produced without the use of fibres might be indicated by study of the mechanical properties of cermets and of the so-called hard metals - tungsten carbide in cobalt. The tungsten carbide dissolves in cobalt and by a process of liquid phase sintering, at a temperature of 1350-1550°C, ie above the solidus temperature of cobalt saturated with tungsten carbide, a very uniform microstructure can be produced, if care is taken, of theoretical density. Values of the work of fracture G_{1c} for various volume fractions of cobalt are given in the table (42).

Binder film thickness (μm)	Grain size (μm)	Vol % Co (wt % in brackets)	G_{1c} (J/m^{-2})
0.16	1.5	14.9 (9)	154
0.29	1.5	23.8 (15)	332
0.38	2.5-3.0	14.9 (9)	297
0.65	2.5-3.0	23.8 (15)	568
1.05	7-8	14.9 (9)	835
1.4	7-8	23.8 (15)	1136

Fracture occurs predominantly but not entirely within the cobalt (43). The fracture toughness bears a linear relationship to binder film thickness with a slope of

$$\frac{dG_{1c}}{d\lambda} = 780 \pm 30 \text{ MNm}^{-2}$$

Where λ is the mean free path in the cobalt. So for a binder film thickness of about one micron a work of fracture up to 780 J/m^2 may be obtained.

11. Rubber Toughening

If inorganics are made by a low temperature route it will be possible to obtain toughening by the incorporation of rubber particles. The increase in toughness due to their incorporation is due to the stretching and tearing of the rubber particles. To estimate the toughness obtainable we can follow Kunz-Douglass Beaumont and Ashby (44). The notched toughness increase due to the incorporation of a volume fraction V_p of rubber particles of mean radius $\bar{r}$, breaking strain λ_f and of average or effective shear modulus $\bar{G}^*$ is given by

$$\Delta G_{1c} = \bar{G}\left(\lambda_f^2 + \frac{2}{\lambda_f} - 3\right) \qquad (3)$$

assuming that the work done in stretching a particle to failure is dissipated when the particle fails. Observation of rubber particles in a rather brittle ($G_{1c} \sim 300$ J/m^{-2}) epoxy resin shows that failure of the rubber particles occurs by tearing in the rubber at or close to the interface between the rubber and the solid resin. The condition for this to occur sets an upper limit to λ_f in equation so that we obtain

$$\Delta G_{1c} = \left[\frac{\lambda_t^2 + \left(\frac{2}{\lambda_t}\right) - 3}{\lambda_t^2 - \left(\frac{4}{\lambda_t}\right) + 3}\right] 4\,\Gamma_t V_p \qquad (4)$$

where λ_t is the extension ratio at which particles tear, which for values of $\lambda_t \geq 1{\cdot}5$ converges quickly to

$$\Delta G_{1c} = 4\,\Gamma_t V_p \qquad (\lambda_t > 4) \qquad (5)$$

where Γ_t is the tear energy of the rubber. It is found that the tearing strain depends on particle size being larger for smaller particles but the overall contribution of the particles to toughness is less sensitive to $\bar{r}$ and the toughness depends just on volume fraction and tear energy of the rubber.

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* For a carboxy terminated butadiene acrylonitrile rubber $\bar{G}$ is about 3G where G is about 1 MN/m^{-2}

Typical tear energies of rubber are between 10^2 and $10^5 J/m^{-2}$ (45). Substituting $10^5 J/m^{-2}$ in equation (5) predicts a value of ΔG_{Ic} of 4000 J/m^{-2} for a volume fraction of rubber of only 1%. However, what measurements there are indicate that the value of Γ_t is somewhat lower for the particles of rubber dispersed in a matrix or in a fibre composite than it is when Γ_t is measured in a specimen of bulk rubber (44,46). This may be due to a limitation in the volume of material involved in tearing when a crack (tear) traverses a small particle and the fact that a small particle at the tip of a moving crack will be deformed at a much higher rate of strain than the specimen as a whole; both factors will decrease Γ_t . With a value of Γ_t of $2.5 \times 10^3 J/m^2$ a volume fraction of 10% will be necessary to obtain a value of 1000 J/m^{-2} for the composite according to equation (5).

12. Toughness of Wood and of Complex Fibres

Jeronimidis (47) presents evidence that the fracture toughness of wood is not due to pull out of fibres. He finds that putting maximum values into the right hand side of equation (1) that the values obtained are an order of magnitude less than the experimental values. He uses (2) to e~~limin~~stimate the pull out length and so must estimate σ_{f} and d the diameter of the entity pulling out as well as τ the shear strength of the fibre matrix interface.

There is some uncertainty in estimating those but Jeronimidis says that pull out over a sufficient length (I estimate the required distance as about 1 mm) is not observed. The toughness is ascribed to the tensile buckling of a helically wound tube strained in tension with the ends prevented from rotating, not in an elastic mode but by shear parallel to the fibres. The wood consists of cells which are helically wound tubes.

This mode of failure could in principle be obtained in a brittle matrix composite if the individual fibres were replaced by helically wound tubes of the same material as the fibre. In wood the fibres in the tubes are composed of the stiff material (cellulose) and so helical winding reduces their contribution to the axial elastic modulus. Any loss of modulus on introducing such complex fibres into an inorganic which is already stiff would not be a disadvantage.

Winding such tubes before introduction into a matrix would be very expensive and it would clearly be best to aim to produce such structures by chemical means.

Other complex fibre arrangements which can increase the toughness per fibre over that obtainable by pull out have been described, eg (48) in which the main fibre is a hollow cylinder containing a crimped fibre as a core. This core may again with advantage be wound into a helical form.

Under these conditions, when the sheath fails in tension the load carried locally by the bicomponent fibre drops by an amount equal to the load carried by the sheath. However if the sheath is designed to fail while the stress carried by the core is less than σ_{max} (the stress on the core element required to drag it bodily through the sheath) the core, bridging the crack, can carry an increasing tensile stress up to the limiting value σ_{max}. When σ_{max} is attained the core is pulled through the sheath against frictural forces, again absorbing considerable energy. Such arrangements have been used on a macroscopic scale as energy absorbing mechanisms. Their production on a microscale would best be carried out in situ by controlled solidification and interface chemistry or some other processing method.

13. Chemical Methods?

What might be described as wholly chemical means of influencing toughness has been described by the late Peter Fox (49) following experiments on the mechanical characteristics of human tooth enamel deformed in compression. The tooth enamel behaves like a stiff sponge of which the sponge cell walls are made of calcium hydroxyapatite $Ca_{10}(PO_4)_6(OH)_2$ and from which liquid is expelled during compression and drawn in again when the load is released. The load-deformation curve in compression shows an increasing slope as the deformation increases and a marked hysteresis. Fox assumes that the channels between fibres are so narrow that electrical effects due to the walls of the channels dominate the behaviour so that the viscosity depends on the zeta-potential of the surface of the channels and the ionic concentration of the moving fluid. If Fox's supposition is correct, there are obviously many chemical tools at hand in order to control the toughness by such a means.

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TABLE 1

ENERGY REQUIREMENTS OF SOME MATERIALS

	Energy Requirement		
	GJ/tonne	GJ/m^3	Annual Production in UK (10^3 tonne)
Finished Products			
Bricks	4	8	12,600
Refractories	2-200	4-400	
Glass	24	60	2,500
Pottery	10-250	24-700	
Intermediate Materials			
Cement	13	29	17,000
Steel	45	356	20,000
Aluminium	230	621	350
Copper	45 (max)	401	70
Plastic Polymers (average)	90	135	2,000

Source: Making the Most of Materials - Science Research Council 1979

TABLE 2 - BASIC CERAMIC FABRICATION PROCESSES*

Method	Starting Materials	Forming Process	Advantages	Disadvantages
Plastic forming	Fine powder + plasticiser + binder	Eg clays, which are naturally plasticised Extruded sections, mouldings Shaped product fired	Large and complicated shapes possible, very cheap and simple, batch processing	High firing temperatures, large volume shrinkages, close dimensional tolerances not possible, considerable porosity is likely
Slip casting	Fine powder + liquid carrier	Thin slip poured into porous mould, hydrodynamic consolidation, high sintering temperatures	As for plastic forming	As for plastic forming
Cold-pressing and sintering	Fine powder + binder	High pressure compaction in steel or tungsten carbide dies at RT, high sintering temperatures	Unfired green compact often tough enough to be shaped mechanically, large batch production possible, low porosities	High firing temperatures, moderate volume shrinkage, only relatively simple shapes possible, area of compaction limited, low length-to-diameter ratio, can be fully automated but high capital costs
Hot-pressing	Fine powder	Simultaneous application of moderate temperature and pressure in refractory dies, (eg graphite, silicon carbide, alumina, refractory metal alloys)	One stage process, binders not required, close dimensional tolerances and near-theoretical densities possible	Only simple and relatively small shapes possible, usually a slow one-off process, low length-to-diameter ratio, high cost products

* From R A J Sambell - Composites, Vol 1, No 5, September 1970, p 279
See also F F Y Wang - Ceramic Fabrication Processes, Vol 9 of Treatise on Materials Science & Technology (1976)

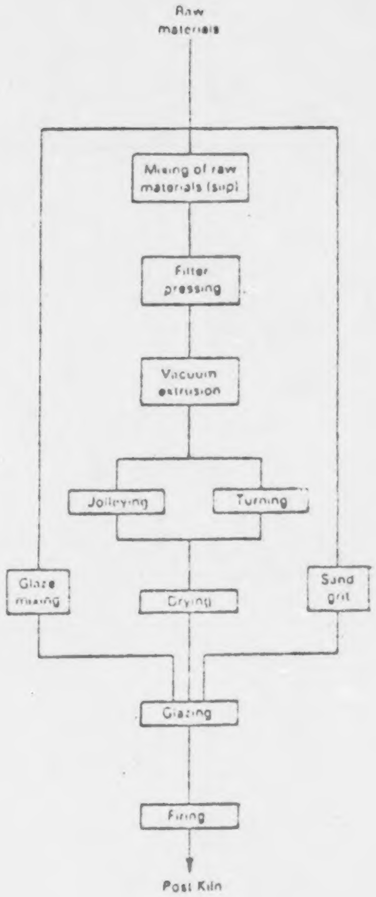

Raw materials
Mixing of raw materials (slip)
Filter pressing
Vacuum extrusion
Jolleying
Turning
Glaze mixing
Drying
Sand grit
Glazing
Firing
Post Kiln

Fig. 1 - Pre-kiln processing of a ceramic insulator

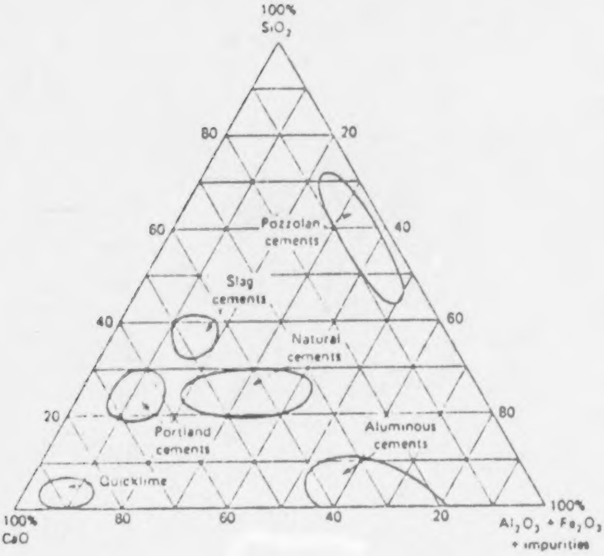


Fig. 2a - Approximate compositions of various cements by weight

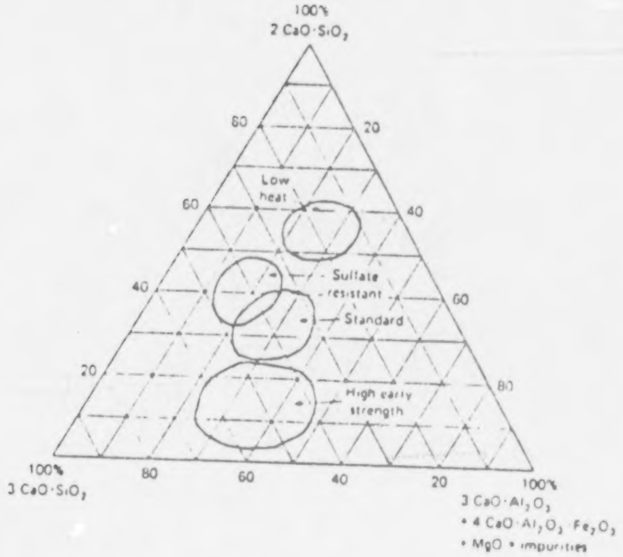


Fig. 2b - Approximate weight compositions of portland cement

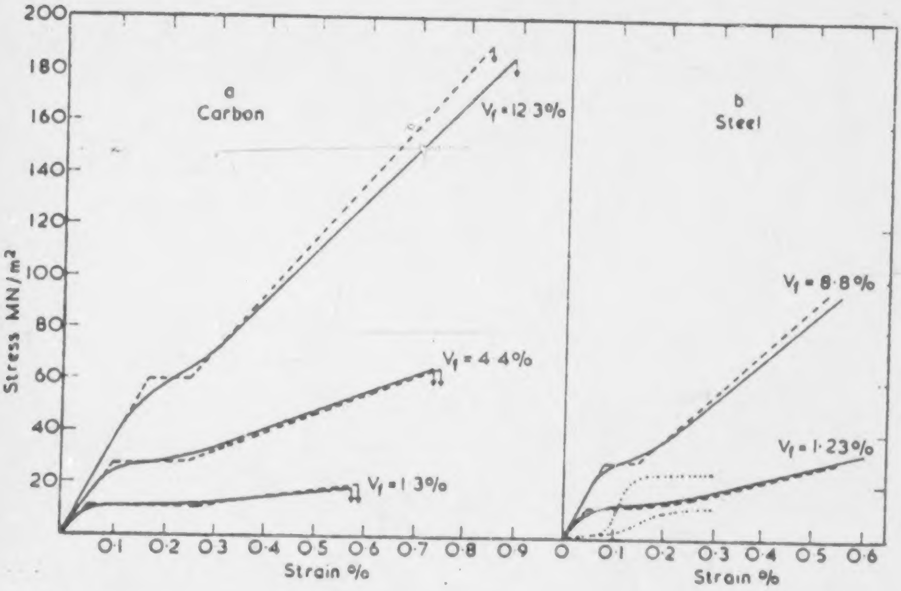


Fig. 3. Stress strain curves of cement paste reinforced with (a) carbon fibres and (b) steel wires. From reference (34)

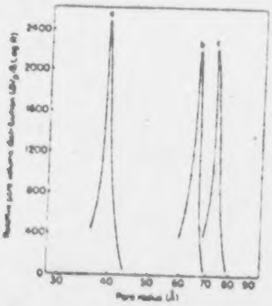


Fig. 4. Pore size distribution curves of specimens a, b and c fired for 24 h at 500°, 900° and 1000°C, respectively (V_p is pore volume, R pore radius)

Mr. **Glickman**. I would like to make sure your slides, which are not a part of your testimony, become part of the record.

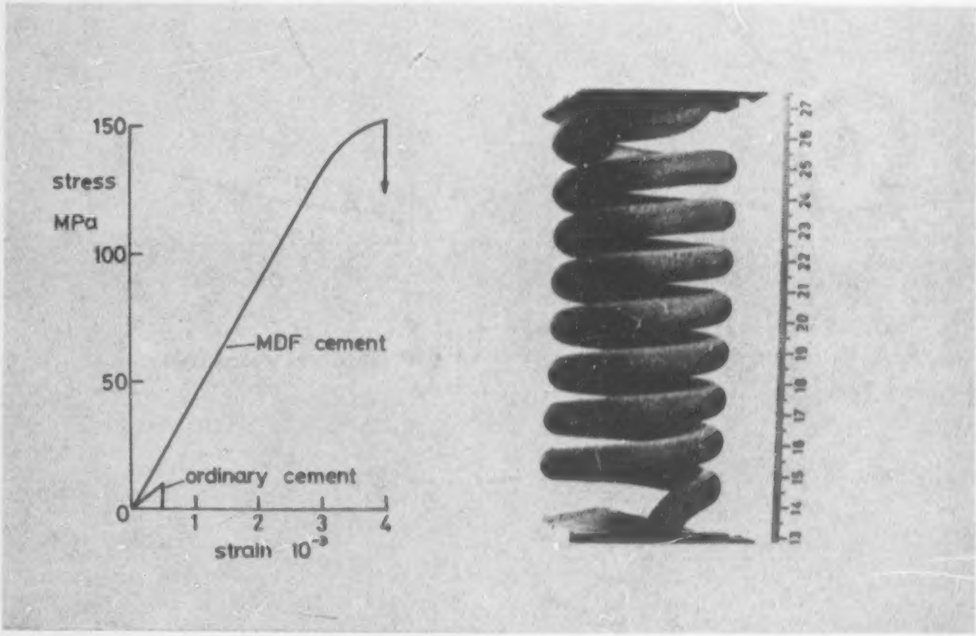
Dr. **Kelly**. The two slides, yes. The first one is in the prepared testimony. It is not in the shortened version that you have there, sir, but I submitted a much larger paper as well.

Mr. **Glickman**. The second slide?

Dr. **Kelly**. The second slide is not, but I will leave the slide with your staff so that it can be put into the record.

Mr. **Glickman**. Very good.

[The information follows:]



Contrasting stress-strain curves for ordinary cement and for Macro-Defect-Free material; also shown in the MDF cement spring (Courtesy ICI p.l.c.)

Mr. **Glickman**. Our third witness today is Dr. Wootan, director of the Texas Transportation Institute, the Texas A&M University system. It is a pleasure to have you here, all the way from, generally, my part of the country.

Dr. **Wootan**. That's generally my part of the country. We're in the same area, anyway.

Dr. **Wootan**. Thank you, Mr. Chairman, and members of the committees. My name is C. V. Wootan and I am director of the Texas Transportation Institute at Texas A&M University. We are an independent research unit specifically organized to conduct research in transportation. We work at both the State and Federal level, performing research under contract to our State department of highways and agencies of the U.S. Department of Transportation.

While we do research in all forms of transportation, more than 90 percent of our work is in the highway field, and the vast majority of that deals with the subject that you are addressing in these hearings—the transportation infrastructure.

I have been asked to speak this morning on the needs for transportation research, and I have been asked also to discuss the adequacy of federally supported basic research in transportation infrastructure and its appropriate relation to the applied research areas.

Let me begin by addressing the adequacy question from a historical standpoint. In 1970 transportation research was considered a relatively high priority item at the Federal level. It had the fourth highest funding level, exceeded only by defense, space, and health. In the 1983 budget it has declined in importance to seventh place. It is now exceeded by Energy, the National Science Foundation, Agriculture, and Interior. Transportation, which is directly responsible for over 20 percent of the Nation's gross national product, is now receiving less than 1 percent of the Nation's Federal R&D budget.

In absolute terms, the situation may be even more critical. During the decade of the seventies, Federal transportation R&D was increased by only about 7½ percent. During this same period the Consumer Price Index increased by 90 percent. In real terms, then, there was an effective decrease in transportation R&D activities amounting to over 42 percent.

At the Federal level, research in the transportation infrastructure is centered largely, if not exclusively, in the Federal Highway Administration. Its budget has generally tracked those of DOT as a whole, showing an absolute decline through the seventies that has continued through 1983. Prior to the passage of the new gas tax bill, approximately one-quarter of 1 percent of the overall FHWA budget was devoted to R&D. It will probably be considerably less than that now.

The question then is, is this an adequate overall R&D effort to protect the national investment of well over $1 trillion in capital improvements that we have made on our highway systems? Is it adequate to assure that we can continue to meet the mobility requirements of our expanding economy and growing population in the future? In my view, it is definitely not adequate by any measure one would care to apply. In fact, in previous discussions I have referred to it as being almost of criminal neglect in transportation R&D.

With regard to basic research, the picture may be even more dismal. The American Association for the Advancement of Science, which performs periodic evaluations of the Federal R&D budgets, does not even list the Department of Transportation among the 11 Federal agencies that conduct basic research. Even by expanding the definition of basic research beyond the classic definition of "the search for knowledge for knowledge's sake" to a broader view that it is really "longer range research," or "strategic planning research," there is very little being done at any level in transportation.

From our own experiences, we have seen a definite move in the other direction. More and more, the Federal program is being directed toward solving very specific problems and in getting those problems solved in the shortest time possible. As budgets get tighter, it apparently becomes more and more difficult to justify research programs that do not have a high probability of success and a rapid payoff. I think this is called getting the biggest bang for the buck. Too often, however, I feel that this philosophy causes us to concentrate unduly on attacking those problems that are urgent rather than those that are important.

This is not to say that the applied programs are not needed. They address problems that definitely need solving. However, they should be only a part of a larger overall program that addresses the longer range issues as well. Had we had a longer range research program in place over the last 10 years, many of these urgent problems may have never arisen. And, until we do get one in place, we will probably continue in the reactive mode of addressing problems only after they arise and have become critical.

Research, both long range and applied, is needed now more than ever before, because our transportation system and the problems it faces is changing more rapidly than ever before. We are facing a growing population with greatly increased mobility demands. At the same time our roadway facilities are remaining relatively fixed and are aging, with many having already surpassed design life. As a consequence, we have both congestion and the need to maintain or rebuild old facilities while still keeping them in operation.

The vehicle population is changing as well. We are going to much larger trucks and much smaller cars. But we continue to operate them in mixed flow on our existing roadways.

Let me just mention a few of the problems that these changes generate and for which we should look to research to help provide a solution.

We know that the smaller automobiles are more vulnerable than those for which our roadways were originally designed. They are more likely to leave the roadway and more likely to generate serious injury and deaths when involved in accidents. They provide less eye height to the driver, and generally have lower acceleration rates at highway speeds.

We also know that the truck weights have been increased and that the economics of operation will create continued pressures for additional increases in the future. Lengths and widths have increased and higher fuel costs will probably continue to influence weight-to-horsepower ratios and thereby acceleration rates. Increased wheel loadings, higher tire pressures, and increased repetitions from more trips will greatly accelerate the rates of deterioration of the roadway system.

We also know that many of our existing roadways, and particularly our urban freeways, are operating above design capacities and that suitable alternate routes are not available to allow closing these freeways while they are being rehabilitated.

Now let's look for a moment at some of the things we don't know and for which answers are desperately needed if we are to effectively, efficiently and safely continue to operate and maintain this roadway system.

Roadside safety appurtenances, such as guard rails, bridge rails, safety sign supports and crash cushions, were not designed for the growing population of ever-smaller automobiles. How can we make these systems safe for the small car and still perform for the larger ones? How can we protect against the spectacular accidents involving the larger trucks? How do we accommodate the mix of heavier and longer trucks and smaller automobiles on our rural two-lane highways? The lower eye height and reduced acceleration rates, coupled with much longer vehicles, greatly extends the required passing sight distances. In a study done 3 years ago, we found that at 50 miles an hour, 200 additional feet were required for the small car to pass another automobile. It also was found that 330 additional feet were required for a standard car to pass a 95-foot triple bottom as opposed to a 65-foot double truck. In combination of these factors, this suggests that many of our two-lane roadways will need to be striped for no passing throughout much of their length.

What is the most cost effective solution to the operational and safety problems this presents? How should we adjust the geometric requirements to accommodate the larger turning radii of the longer trucks in our urban areas? We think we know how to design a new roadway to accommodate a given set of wheel loads and repetitions. We still do not know how to accurately predict the effect of incremental wheel load increases on older pavements that were designed to lower standards.

While we have bridges that have been evaluated and determined to be inadequate, we still do not have a way to accurately evaluate the remaining structural capability of many of our older structures.

Many of our bridges and overpasses have badly deteriorated decks. What new materials or processes can be developed to allow us to replace these decks rapidly and efficiently while still continuing to keep these facilities open to regular traffic.

We do not know how to most effectively accommodate the larger trucks on our higher type facilities. Should special lanes be designated and rebuilt to withstand the heavier loads, or should we continue to build all lanes to accept the full mix of traffic? Should we completely separate the truck and automobile traffic by building separate truck facilities in our more congested urban areas, for both structural and operational reasons?

Since we cannot close our major freeways in many areas, we must make repairs or rebuild them under traffic, and often at night. For several reasons, this presents unusual safety problems. How do we protect our work force while they are engaged in these activities?

Finally, in order to be able to plan ahead, to use efficient budgeting and to apply timely and cost-effective maintenance methods, we need to know the actual rates at which our highways deteriorate and how these rates are affected by traffic and climatic factors. We need to be able to predict future damage and arrive at equitable cost allocation methods. In short, we must develop efficient means of managing our investments in the Nation's highways in order to make the most efficient use of our tax dollars.

These are only a few of the problems that research needs to address. They are not intended to be all inclusive. Some of them are quite specific and fall into the category of applied research. Others demand a longer range and more comprehensive program. They may involve questions of policy as well as a combination of a wider range of research disciplines. I hope, however, that they demonstrate that an expanded and broadened Federal research program is necessary if we are to protect the tremendous investment in our existing transportation infrastructure while continuing to meet the growing and rapidly changing needs of our Nation.

Mr. Chairman, that completes my statement.

Mr. GLICKMAN. Mr. Gore?

Mr. GORE. Thank you very much.

I am fascinated by the testimony presented by this panel. Really, it is not only interesting, it is quite troubling because, taken together, your statements make up a powerful criticism of the R&D policies currently being followed. I must say, on the basis of other testimony we had, I have to agree with the thrust of your comments today.

Former President Nixon's research head had research in cement and highway materials as his top priority; is that right?

Dr. ROY. In one of his major policy statements he had emphasized this. As far as I could see, it fell pretty much on deaf ears and did not feed down into the structure that funds and coordinates research.

Mr. GORE. Why do you think it has fallen so far down the priority list, Dr. Roy? You say what this administration is doing won't be felt for 20 years, and then will be felt overseas before it is felt here. They have eliminated the Center for Building Research at the NBS and a number of other programs.

What do you think is the reason for that?

Dr. ROY. Cement and concrete, I suppose, because it is a basic, common structural material, suffer from the tendency on the part of many people to say that it exists, it will perform, no matter what you do to it; whereas some of the more exotic materials may realize perhaps quicker payoff in terms of visible hardware that catches people's attention. So priorities tends to favor the exotic materials, saying the others have performed in the past and they will continue to perform in the future, rather than attempting to make them better.

I think perhaps it is only now, when attention has been called to the breakdown of the highways, and the immense need for repairs, which can vividly attract the public's attention and it will filter back up.

Mr. GORE. It is sort of the mistake, the basic mistake, that Dr. Gomory referred to in his testimony, about R&D methodology, of becoming so entranced with the computer chip that you don't pay any attention at all to the typewriter hammer hitting the paper.

Dr. ROY. Right.

Mr. GORE. I read recently about this latest breakthrough on the low end computers, incidentally, by Coleco. I don't want to mention—they're not directly competing with you anyway, it's a different market. But their real breakthrough was in the engineering of the basic materials, taking things off the shelf that were available cheaply and, through research, finding out how to integrate them to the typewriter part of the system.

When it comes to America's R&D effort, you're saying it is a mistake for us to become so entranced by the exotic possibilities in high energy physics that we just put all the money there and completely ignore where the tire hits the road, where the rubber meets the road. That's essentially what we're doing, is it not?

Dr. ROY. I think that's true. There is no reason we shouldn't be putting some of our best brains, or better brains, at least, toward solving some of these problems for the transportation system.

I think Japan is always a good country to quote because they seem to have an ability to identify problems and get together the sustained combination of university, Government, and industry to work on research and take it through to the stage of development, to identify problems. They have quite an enormous capability in cement and concrete research and ceramic research.

Mr. GORE. Professor Kelly?

Dr. KELLY. I would like to make a comment there, because I think there is a technical problem where the government really can help.

Cement is very peculiar in that there is research on the method of making it, but it is no one's responsibility in a sense to do research on its properties once it's made, because it is sold in a way that—it comes in a bag and it's mixed with water by the customer, who then has the artifact. That way there is no economic incentive for someone to work on the new properties of the material. It is just the sort of place where some outside funds are needed.

Mr. GORE. That's a good point.

Speaking of cement, the new cement materials that you mention in your statement, Dr. Roy, how far away are we from standard use of those new cement materials?

Dr. ROY. We are probably rather far yet. In the case of our own research, it was taken to a certain stage and essentially dropped because there was not the mechanism for following through on it. I think it is akin and somewhat related to the material that Professor Kelly has described in England, where they used a somewhat different approach and have been able to take it farther. So perhaps he would like to comment on how that came about.

Dr. KELLY. Well, it is a good example of the network approach. The material is patented. It has been developed by ICI. The university assistance that has arisen has been from my own University of Surrey and the University of Oxford, and there has been a small input from a Government lab, the building research establishment. But the prime lead has been from the work done in industry, with perhaps some thinking input from the universities. But I think it is not far along because the industry itself is making the material, rather than developing it ex-house.

Mr. GORE. Who funds your research in cement and materials?

Dr. KELLY. We are funded by the Science and Engineering Research Council, which is the equivalent of your NSF, I believe, and a little by the Department of Industry, and in the cement research at Surrey, a major part from Redland Technology, which is a construction company. They do that principally by personnel. We have two visiting professors, one of whom is paid halftime by Redland.

Mr. **Gore**. It would help us to get a better view of what the program is here in this country if you could give us an idea of your annual level of funding there.

Dr. **Kelly**. At Surrey, or in the U.K. generally?

Mr. **Gore**. Both, if you would.

Dr. **Kelly**. Well, at Surrey the funds are very small. They wouldn't amount to more than £100,000 per year, $150,000. That has been over an extended period and we can rely upon it.

In the U.K. at present, I would have to make a very wild—well, it would be no more than a guestimate, sir, I'm afraid. But I would doubt very much if it's more than—just give me a moment and I can——

Mr. **Gore**. You can submit that for the record.

Dr. **Kelly**. OK. I can give you an accurate answer the day after tomorrow.

Mr. **Gore**. That would be fine.

[Material follows:]

The funding level in the United Kingdom for cement materials research is around 17 million pounds per year, plus or minus 5 million pounds.

Mr. **Gore**. Yes. We will put it into the record.

Is there any way you can give me an appreciation of how it ranks compared to other areas of research? We have been talking about the effort here in the United States as being neglected and really being hurt because of a lack of attention——

Dr. **Kelly**. I think that's generally true.

Mr. **Gore**. What about in England?

Dr. **Kelly**. I don't think it is fashionable—it is becoming better known because of some of the recent work, but we do not get the best brains in cement research. We have been fortunate in having one or two clever people like the inventor of that spring material, but we do have the same problem as you.

Mr. **Gore**. Do you have the same problem of top management turnover that we have heard about in the U.S. programs?

Dr. **Kelly**. That is certainly true, yes.

Mr. **Gore**. We have a lot of turnover and we can't have continuity for that reason.

Dr. **Kelly**. Yes, that has happened in some of the chemical companies. I think it is a problem, yes, but I don't think it is really the major problem. I think the major problem is the one we have referred to, that it is an unfashionable material and it is nobody's job to fund research on it.

Mr. **Gore**. Dr. Wootan, in your testimony you trace the substantial decline in Federal support for highway transportation research to what you describe as a "definitely inadequate level." Elsewhere you have been heard to characterize the Federal attention to highway research as "almost criminal neglect." You also state that we need an expanded and improved Federal research program.

What organizational and operational directions would you build into an expanded program?

Dr. **Wootan**. To be certain, Mr. Chairman, I don't have solutions to all these problems. I think I can help identify some of the problems. We have the problem, I think, in terms of fragmentation of what small Federal research funding is available.

I think we have a problem that I think sort of addresses the one on cement, the problem of perception and salesmanship. It is much easier to sell a 10-year program of research in high energy physics because the general population sort of assumes it takes 10 years to solve something in high energy physics, because they don't understand it. It is much more difficult to sell a 10-year program on fixing a pot hole or developing materials and processes that will allow you to repair pot holes and keep pot holes from appearing because the general perception is you ought to know how to do that anyway. So we have a salesmanship problem within the DOT agencies themselves. I think they feel they have to have high visibility activities that they can demonstrate to the Congress, and that this is in a cyclical 2-year type program, that they have to have benefits produced at least every two years in order to maintain their research programs.

So I would say we need to have a mechanism by which we can allow more innovative approaches to solving some of these problems, that will allow us to bring together greater interdisciplinary attacks to some of the major problems, including some of the policy-related problems that we are facing. This really doesn't fit too well with the procurement processes that the Government uses, and I understand why those procurement processes are tight like that. But it is very difficult to issue procurements on a general base of doing a 10-year program in an area of research to come up with a generalized answer. It is much easier and much more defendable to say you will do one, two, three, four, five and you have something you can measure against—was it done or was it not.

So I think the procurement process is not well suited to it. We have a very small pie to begin with, then when you try to attack a whole bunch of problems it naturally fragments it. I think it is forcing us to work on those problems that appear to be more visible, more suitable to getting an answer back.

Mr. GORE. I have just one other question.

Are engineering colleges and graduate schools adequately educating and training future researchers and research managers in this area of highway transportation and infrastructure? Do you think they're doing an adequate job now and, if not, what needs to be done to improve it?

Dr. WOOTAN. In order to be able to really have a——

Mr. GORE. With the exception of Texas A&M.

Dr. WOOTAN. With the exception of Texas A&M, they're not doing too well. [Laughter.]

Mr. GORE. And I won't ask you to comment, Dr. Kelly. We're only talking about American universities.

Dr. WOOTAN. I think we have a real problem, which we have all experienced—we have, and I know Penn State has, and all the other major engineering universities—in attracting and supporting graduate students. We have had a problem of just getting the numbers of graduate students that we should be getting and turning out. I think the universities face a very trying time in the future. We are not educating and training people who can teach in the universities in 10 or 15 years from now. We're going to hit a big gap in that area because we do not have the graduate programs.

In order to sustain graduate programs, we need a viable research program. The two must go hand in hand. You can't have an effective graduate program without having a research program. Now, that can be funded from many different sources, but you do have to have a research program to be able to support and train your, Ph. D. level particularly, engineering graduates. I think we are woefully behind in that area now and face some serious consequences in higher education 10 or 15 years down the pike.

Dr. ROY. I think that very much follows through. In our university it is certainly the case. The students at the bachelor's level, if they can land a good job rather quickly, are more likely to jump to it if they do not see any immediate possibility of a research establishment into which they can productively go.

Now, there have been one or two examples counter to this in the cement and concrete applications in nuclear waste. We have been able to do a little bit because we got Department of Energy fellowships for some graduate students at the master's level, and they would sense that, because someone would give them a fellowship, that there probably would be a job at the end, that somebody really wants their increased skills at the end of that period. So this sort of thing can be encouraging. But to continue on to get competent people in the future as teachers, as well, is an enormous problem.

Mr. GORE. Thank you, Mr. Chairman.

Mr. GLICKMAN. Thank you, Mr. Gore.

Professor Kelly, is the concrete and asphalt on the roads in England or in Europe of different consistency than they are in the United States?

Dr. KELLY. I think the individual mixes are, because they are based on local raw materials, but I don't think essentially they are different as far as I know.

Mr. GLICKMAN. The bridge technology, the infrastructure technology, is based more upon different locales and how close you are to quarries and what kind of materials you're going to get, rather than on technological variables. The Germans or British or the French don't have any novel techniques that we're missing out on in terms of road construction?

Dr. KELLY. Not so far as I'm aware, sir; no.

Mr. GLICKMAN. Dr. Wootan, do you have any figures on the potential fatalities and property damage that the changing mix of cars and trucks may cause if nothing is done to fix existing highways and bridges?

Dr. WOOTAN. I don't have any specific figures, Mr. Chairman. I think that it is safe to assume, in just visualizing the problems, that it will be substantial because of the very serious inequalities of that mix. Any time a small car hits anything, it is bad news; but if it hits a big truck, it is really bad news, not only because of the structural crushing capability, but also the difference in the forces. So I think we are facing real serious safety problems as we continue this increasing expansion on either end of the spectrum rather than as we had traditionally done, having most everything operate in sort of the middle of a size scale.

Mr. GLICKMAN. I assume from that that if a small car hits a truck, you're saying the problem is worse than a big car hitting the truck. But I assume if a small car hits a big pothole——

Dr. WOOTAN. It is still worse.

Mr. GLICKMAN. It is worse than for a big car.

Dr. WOOTAN. Yes. It has stability problems that cannot accommodate discontinuities in the roadway as well as a big car can, so they are more likely to go out of control and more likely to get in trouble hitting a pothole or a curb, things such as that.

Mr. GLICKMAN. Mr. Carney.

Mr. GORE. If my colleague would yield, I just wanted to make a special note of this new phrase that I have learned today, "roadway discontinuities" instead of potholes.

Dr. WOOTAN. That's potholes, yes, sir. [Laughter.]

Mr. GLICKMAN. Mr. Carney.

Mr. CARNEY. We might be going down some treacherous roadway here with the muffler and front-end group in this country. We should be a little cautious with that. There might be some political negatives there.

Dr. Roy, I had a chance to briefly go over your testimony, and to all the panelists I apologize for not being here to personally hear your testimony. However, ironically, I was a witness before the Surface Transportation Subcommittee trying to get the longest parking lot in the world, the Long Island Expressway, into the Interstate System. So I had a conflict and I hope you will excuse me.

However, I noted, Dr. Roy, in your testimony you feel that one of our problems is the appeal to fund these types of research programs is on a lower echelon than perhaps to fund a telemetry program to monitor the temperature of an astronaut, something of that nature; therefore, we run into a problem.

I think we have another problem. If we were to fund $30 million, let's say, for a program that you might call the "molecular intercourse of roadway materials," the gentleman in the other body would be fast to put the "Golden Fleece Award" on it. So it is not only a problem from the standpoint of laboratories and priorities in the R&D community, but it is probably a problem that we are faced with here, having the political courage to say "let's spend a lot of money on cement" or "let's spend a lot of money on asphalt."

I think not only this panel but every panel so far, Mr. Chairman, has clearly brought that to the members of this panel's attention, that we are just dealing with a topic that doesn't have the appeal. So, one, you point that out.

The second thing—and perhaps it wasn't this panel—they pointed out the problems with bidding on projects because we have a system that says the low bidder gets the job, and for someone to go out and enhance the quality of a road surface and, therefore, perhaps make the price go up, that construction company is not going to get the bid. So it discourages private enterprise from getting into R&D.

The only way I could ever see anything happening, unless we can break this block, is if private enterprise could come up with a better mousetrap which at the same time would be cheaper. But then they have the problem of the Federal Government saying they don't meet the specifications and we're not willing to take a chance on your new wonder product. So that brings us to the next problem, and this is really what I want to ask.

How can we accelerate the applied testing of new products so that we can get some of them on our highway systems, and in so doing as well, eliminate the popcorn pavement that my colleague from Tennessee brought to our attention? In other words, we can forcefeed a rat and take saccharin off the market, but how can we forcefeed a highway surface and say this maybe has possibilities, or this obviously has no application at all?

I throw that question out to the three distinguished panelists.

Dr. Roy. If I could respond first, I think this is going to require a high degree of coordination. Of course, your $30 million Golden Fleece Award is a good candidate for what not to do.

At the upper end of this R&D pyramid—upper or lower, however you treat it—I think there has to be a relatively small amount of long-range research that would be coordinated with and fed into by all the other parts of the program. There may be no shortcut to getting all your answers, so I would first make a plea for some small amount of sustained effort, such as Dr. Kelly pointing to one example of success where effort was sustained over perhaps a 10-year period. Perhaps most of your projects will still have to go out on competitive bids. But if it is possible, by some organization to identify the top priorities, and then pinpoint some of these for a more sustained effort, many things can be accomplished in a laboratory situation more quickly than testing on the pavements of 50 States, for example. Both have to be done. But I think you need a mix.

Dr. Wootan. Yes, Mr. Carney, I think there are a great number of things that we can accelerate in the laboratories. We do it with materials, such as running them through accelerated freeze-thaw cycles, for example, to determine how well it will hold up under freezing and thawing conditions.

There are other things, such as how well the material will react to different climatic conditions that may exist over the country that really we don't have a good laboratory mechanism to simulate those now. You really need to have them down and in place in the field for a period of time before you can be certain. You know, you can think you know how they should perform, but in order to verify their performance in the field, I don't know of a way to speed up that process of putting them down in the field and seeing how they perform over time under actual conditions.

Mr. Carney. Professor Kelly?

Dr. Kelly. I think you have three problems. You have a visibility problem, you have a risk problem, and you've got the standards problem that you referred to at the end. I think the visibility problem is gotten over just by asking questions like this and giving prominence to the fact that there are very important scientific and technological things that can be done in a material that has been around a lot, but where there has not been the brainpower or money spent on it. That can be gotten over by publicity, to some extent, and attracting the bright young scientists and engineers in the universities into these fields. My colleagues have dealt with that.

You then have the risk problem of the development of new things, who is going to bear the risk and can you minimize that. I personally think that is where you want to try and get away from double-sourcing philosophies and form often a user-supplier relationship or some form of consortium, where both are sharing the risk and both share the reward. Now, that runs counter sometimes to the perceived wisdom of how business should operate, but sometimes with new things it has to be done and it is done in times of crises when the Government has to have things. When you referred to astronautics, that's where that happens.

Then last, the standards problem, that again I think comes back to the visibility and people realizing it would be better if we had better roads and, therefore, if a new material comes along, we may need to rewrite the specifications. It is always done by a group. The writing of standards and specifications is a mixture of users, officials, and so forth. Again, they have got to feel that we need a change. That goes back to the visibility problem.

Mr. CARNEY. Dr. Wootan pointed out how—I think this is what you're saying—how the ultimate laboratory is the road surface itself, that has 18- and 22-wheelers going over it and a certain amount of automobiles on an everyday basis. That becomes a problem in our Nation. I might say Professor Kelly doesn't have that same type of problem in England, inasmuch as we go from the Everglades of Florida to Alaska. The climate changes there and the requirements are far greater.

I think we are a nation that has switched from railroads to road surfaces, and the demand on our Interstate System as well as our primary and secondary roads is just absolutely incredible, as was brought out in some of the opening statements on the first day of our hearings. It complicates the problem immensely.

My last question is, as we go along with the current, admittedly inadequate R&D programs—and I think it would be only fair to ask this of our American colleagues—no, come to think of it, I will ask it of all of you, because maybe Professor Kelly can shed some light on this, too.

Do we continually have an emphasis not only on the strengths and durability of the composites that perhaps would be the future road surfaces of the country, but at the same time ascertain the factors such as skidding and water drainage and that type of thing, a concurrent type of R&D?

Dr. ROY. Yes. Obviously, all these factors have to be concerned. I think probably durability at the moment seems to be the most difficult. This seems to be the more sticky problem right at the moment, but obviously that has to be a component of the total effort. Especially with skid testing, that finally has to be done out in the field, but probably not in all the States but in representative ones in the different climatic areas.

The costs in the laboratory are so much lower that all that can be done to start out with will pay off many times over.

Mr. CARNEY. Mr. Chairman, I asked that question because you were pursuing a line of questioning that I thought was very, very important, and that was were there statistics as to the number of deaths and injuries that could be attributed to the poor surfaces on our highway system. That is significant because of the public perception, the problem we have with getting research and development done on cement or asphalt.

However, if we look back in the last 2 years in our Nation, we recognize the great problem in our highway system, and the problem of drinking and driving and the related deaths, and the number of Americans, unheard of before, who are rallying behind the cause to prevent that, perhaps if we can take that thought and say, "Do you know that 10,000 people a year die in our Nation because of potholes or unsafe exiting ramps", that type of thing, we could get the types of support to go back to the basic research necessary to find the answers to these problems we are confronted with.

I apologize to the panel for ending in a statement. I don't think that's proper. We are here to listen to you. But I think the chairman was pursuing that as an avenue of getting around some of the problems you have enunciated.

Mr. GLICKMAN. I think that your statement is a cogent one and an important one. One of the things perhaps, Dr. Wootan, you would have that I'm not sure the Government has, is some way to quantify those statistics in a better fashion than we do now. Any information you would have to help the committee in trying to quantify the relationship between road surfaces, fatalities, the cost of maintaining automobiles, that kind of thing would be useful to us.

I would just mention finally before you leave, this last weekend I rented an E-class Chrysler car, which drove quite well. But I was struck by the level of research, because when I got in the car the car proceeded to tell me my door was open. Then when I forgot to turn on the headlights, it told me to turn the headlights on. And when I left the key in the car, it basically told me I was an idiot for leaving my key in the car.

It struck me that, in our discussions with the prior panel we were figuring out what research was supposed to do for us, but after being in that car for 30 minutes, it drove quite well but I would never buy one, or if I did buy one, I would disconnect that horrendous voice in the front of the car telling me what to do.

Mr. CARNEY. Particularly after it asked you to get a "Big Mac" and chocolate shake.

Mr. GORE. Well, they made a mistake in making it Lee Iacocca's voice. [Laughter.]

Mr. GLICKMAN. In any event, it is a useful parady on the kind of research that we do and how it transfers to the market as appropriate technology. I relate it to the kinds of things we have been talking about today.

We appreciate very much your excellent testimony today and look forward to any further input you can give us.

We will be back in about 15 or 20 minutes.

Dr. WOOTAN. Thank you, Mr. Chairman. It is a pleasure to be here.

[Whereupon, the subcommittees were in recess.]

Mr. GLICKMAN. Why don't we conclude with our last panel. Again, I apologize for the vagaries of the House. We may be having another vote in about 20 or 25 minutes, so again I would tell you that in connection with your testimony and judge it accordingly.

The last panel is a group of folks who will be talking about research and transportation infrastructure materials with particular emphasis on developments in cement and asphalt which, of course, are probably at the heart of what we are talking about today. Each of your statements will appear in full in the record.

It is a pleasure to have you here, and why don't we start with William Young, president of the Portland Cement Association, Skokie, Ill.

STATEMENTS OF WILLIAM J. YOUNG, PRESIDENT, PORTLAND CEMENT ASSOCIATION; GERALD S. TRIPLETT, PRESIDENT, THE ASPHALT INSTITUTE; AND DR. RICHARD W. SMITH, DIRECTOR OF RESEARCH AND DEVELOPMENT, NATIONAL ASPHALT PAVEMENT ASSOCIATION

Mr. YOUNG. Thank you, Mr. Chairman.

The organization I represent is the research, public affairs, and market development arm of the portland cement manufacturing industry of the United States and Canada. Ours is a small, fragmented industry. In the United States there are some 45 corporate entities that produce portland cement. The gross value of our product is about 10 percent that of Mr. Gomory's company, which he reported as being $30 billion in sales, and we're a little over $3 billion.

We do represent in our association about 75 percent of the U.S. cement manufacturing capacity, and we employ about 360 people. Our members basically make portland cement, and I would simply like to point out briefly a clarification on the product. What we produce is this powder [indicating], which is a raw material in the production of concrete, and it binds sand and stone together to form this rock-like substance [indicating].

We have been asked to comment on the adequacy of current research to improve construction practices in pavement materials. Now, other witnesses have been testifying about the way the public sector is reacting to these needs, and I will therefore confine my remarks to the private sector research question.

I would like to leave you with these three thoughts:

First, the amount of research sponsored by the cement and concrete industry in highway and bridge construction has declined sharply. This decline is an outcome of the severe recession in construction and of longer term economic problems in our industry.

Second, both public and private research to improve construction methods and materials should be encouraged through public policies that would put a premium on long-term quality rather than low first cost.

Third, because all public construction projects are paid for by the taxpayers, it is the taxpayer who reaps the greatest benefit from construction research. For this reason, we urge greater use of cost sharing by public and private agencies to fund such research.

Let me turn first to the question of the economic problems facing our industry and the impact on research activity.

Our industry is just now beginning a slow recovery from several years of declining shipments and even more sharply declining profits. Cement use last year was at the lowest point in the past 20 years. Construction generally has declined as a share of the gross national product. It accounts for 6 percent of GNP today, compared to twice that much in 1950.

During the same time the cement markets were declining, the capital demands on our industry were tremendous. We had to respond to the OPEC prices by converting to coal as our principal fuel source. We had to adapt our plants to conform with the requirements of the Clean Air Act, and we had to replace high-cost plants with new technology.

This first chart shows the sharp increase in capital investment by the cement industry, all in a period of high interest rates and a gyrating demand for our products. In this kind of economic climate, it is little wonder that research was one of the "extras" that had to be sacrificed or curtailed pending a return to better times.

I should explain that in our industry research is of two types—that carried on by individual cement companies, and that conducted by the Portland Cement Association laboratories with funds provided by our member companies.

The second chart shows the sharp decline in the number of cement companies that carry on their own research programs. Although we don't have precise data, we believe that the dollar volume of this lost research is even greater than the two-thirds decline shown here.

The third chart shows the decline in research of the Portland Cement Association. Again, this reflects the extremely low profitability for most cement companies.

I should point out, too, that in both cases here we are talking about all kinds of research, PCA and private, and the research in highway-related subjects alone would constitute about 25 percent of the total activity.

Thus far I have alluded to the economic deterrents to higher levels of cement research. There are structural deterrents also.

For example, public construction contracts traditionally, and often by law, are awarded to the low bidder. While this practice historically has been considered necessary to the public interest, the low-first-cost concept is a serious deterrent to new product development, quality imrovement, and innovative technology. In construction, as in most activities, quality demands a premium.

Cement is, of course, a commodity, and every manufacturer makes essentially the same product. New developments, therefore, cannot be proprietary; they must be disclosed openly so that public agencies can include them in product specifications which must be followed by all bidders. This is a further deterrent to materials research because the benefits of innovation are so hard for the innovator to capture.

Thirdly is the one I referred to earlier. It is the taxpayer, not the cement producer, who benefits from new developments. This means the cement manufacturer has little economic incentive to invest in the type of proprietary research which other companies and industries thrive on.

Next I would like to comment briefly on what we can expect from higher levels of construction research. But first let me correct a popular misconception regarding the present poor condition of America's highways and bridges. Some may attribute our present problems to a lack of research in the past. Would more research have prevented many of today's problems? Possibly, but not likely.

The reason our highways and bridges are in need of repair today is threefold: One, most of the Interstate System has simply outlived its 20-year design life. That's as long as it was supposed to last. It was expected to need renovation after 20 years. Second, the traffic on many highways is three to four times greater than expected at the time the roads were built, and finally, the allowable vehicle weights have increased in the past two decades. This, of course, shortens the useful life of highways designed to carry lighter loads. The wonder is not that our highways are in need of rehabilitation, but that they are still performing as well as they are.

Having said that, let me emphasize that more intensive research can produce dramatic benefits. Let me cite just one example.

Nearly all structural concrete contains steel reinforcement in some form. High-strength steel reinforcement was being used in buildings in the early sixties, but there had not been any research to show that this steel would stand up under the moving loads on bridges. Until there was, it could not be used in bridge construction.

In 1971, the PCA and the Federal Government got together on a cost-sharing basis to develop the needed information. Now, as a result, all reinforced concrete bridges can be built with high-strength steel at a 30 percent lower reinforcing cost. Translated into dollar savings, this means that taxpayers are saving at least $30 to $50 million every year on this one item. This represents a research payback of $100 in savings for every dollar originally invested.

Future research may offer even greater potential. For example, specialty cements now under development will make it possible to make pavement repairs or to place new overlays that can be back in service in 15 minutes and still provide a long service life. This means faster construction, lower maintenance, and a much lower annual cost for such highways.

Moreover, new materials like fiberglass reinforced concrete and modern high-strength concrete now being developed for bridges can drastically reduce costs and make bridges virtually maintenance free.

It is evident, then, that public agencies—and this means the taxpayers and highway users—can expect large dividends from more and better research in highway and bridge materials and construction. The question remains, how and by whom will this research be carried out.

One approach—and it is one I don't relish—is to rely on other nations for the needed research and technology, just as we have surrendered technical leadership in other industries. Or we can do what is necessary to put our Nation back on track in this important area. We suggest the latter course is the only rational approach and we recommend the following four specific steps:

One, that public agencies, as agents for the American taxpayer, who really benefits from all this, increase their research participation with private industry on a cost-sharing basis.

Two, that more emphasis be placed on durability and quality of construction. This would create added incentive for materials producers to invest more in research and product development.

Three, that a larger share of present highway planning and research funds go into research. We understand that 1.5 percent of Federal highway expenditures are earmarked for HPR purposes—highway planning and research—but that less than one-quarter of such funds go for materials-related research, with the remainder, the vast majority, allocated under the general heading of "planning."

Finally, that more extensive use be made of the research capabilities of private industry, such as our own research located in Skokie, Ill., near Chicago.

Gentlemen, we have here a great opportunity to develop an efficient and productive partnership between Government and industry. On behalf of the U.S. cement industry, I pledge our continuing cooperation toward that end, and I appreciate this opportunity to speak to you.

[The prepared statement of Mr. Young follows:]

PORTLAND CEMENT
ASSOCIATION

TESTIMONY BY WILLIAM J. YOUNG
PRESIDENT, PORTLAND CEMENT ASSOCIATION

Joint Hearings on Problems of and
Prospects for Research in
Transportation Infrastructure,
Especially Highways and Bridges

Subcommittee on Investigations
and Oversight and Subcommittee
on Transportation, Aviation, and
Materials

Committee on Science and Technology
U.S. House of Representatives

June 15, 1983

Joint Hearings of the Subcommittee on Investigations and Oversight and the Subcommittee on Transportation, Aviation, and Materials of the Committee on Science and Technology, U.S. House of Representatives

Washington, D.C.
June 15, 1983

Testimony of William J. Young, President, Portland Cement Association:

Mr. Chairman and Members of the Subcommittees:

My name is William J. Young. I am president of the Portland Cement Association. The organization I represent is the research, public affairs, and market development arm of the portland cement manufacturing industry of the United States and Canada. Our membership of some 40 companies represents about 75% of U.S. cement manufacturing capacity and 100% in Canada. We have a total staff of approximately 360, of whom some 70% are specialists in engineering, physics, chemistry and other technical and research disciplines. We have headquarters and a large research center at Skokie, Illinois, and offices in major cities, including Washington, D.C.

Essentially our member companies all make the same product--portland cement. Among laymen and even among some in the building industry the terms "cement" and "concrete" are often used erroneously. Actually cement--the product manufactured by our member companies--is just one ingredient of concrete. Portland cement is a fine gray powder that is mixed with water to form the "glue" that holds sand, gravel, or other minerals together to form concrete--the hard, durable material used for many construction applications, both structures and pavements. Since nearly all cement ends up as a part of concrete, my comments today will deal with both materials.

As requested, my testimony will summarize our industry's views on the adequacy of research now being carried out in the United States to improve construction practices and pavement materials. It is my understanding that several other witnesses will be addressing research programs and needs in the public sector. For this reason I will confine my testimony primarily to the status of transportation research in the private sector.

Briefly, here are the principal thoughts I would like to leave with you today:

First, the amount of research sponsored by the cement and concrete industry in highway and bridge construction has declined sharply. This decline has been a direct result of the recent severe recession in construction and of longer-term economic problems besetting the cement industry.

Second, both government and private sector research to improve construction methods and materials should be encouraged through adoption of public policies that would put a premium on long-term quality, durability, and low annual cost rather than low first cost, a practice which now governs the bidding and award of public construction contracts.

Third, in the final analysis all public construction projects are paid for by the taxpayers. It is therefore the taxpayer who reaps the greatest benefit from research in construction and building materials. For this reason we urge greater use of the principle of cost-sharing between public and private agencies in the funding of transportation-related research.

Now, to return to the first of these three points--the long-standing economic problems facing the cement industry and their impact on research expenditures.

The industry is just now beginning a slow recovery from several years of declining shipments and even more sharply declining profits. Cement use last year was at the lowest point in the past 20 years.

Most of this decline can be attributed to the decline in construction generally. In 1950, construction accounted for 12% of GNP. By 1970, it had dropped to about 10%. Today construction accounts for barely 6% of GNP.

During this same period of declining markets, the cement industry was faced with tremendous capital needs especially to improve its energy efficiency and productivity and meet environmental standards.

After the OPEC action in the early 70's we had to convert quickly from oil and natural gas to coal as our principal fuel and today that conversion is virtually complete. We also had to invest well in excess of $100 million for retrofitting existing plants to meet the stringent requirements of the Clean Air Act. At the same time we had to replace many older, inefficient plants with the new technology necessary for our economic survival.

Exhibit 1 shows the sharp increase in capital investment by the cement industry--all in a period of high interest rates and gyrating demand for our product.

In this kind of economic climate, it's little wonder that research was one of the "extras" that had to be sacrificed or curtailed pending a return to better times.

I should explain that in our industry, research is of two types--that carried out by individual cement companies, and that conducted at the Portland Cement Association laboratories from funds provided by our member companies.

Exhibit 2 shows that there has been a sharp decline, from 18 to 6, in the number of cement companies that carry on their own research in cement and concrete. Although we don't have precise data, we believe that the dollar volume of this lost research is even greater than the two-thirds decline shown here.

AVERAGE ANNUAL CAPITAL INVESTMENT BY CEMENT INDUSTRY

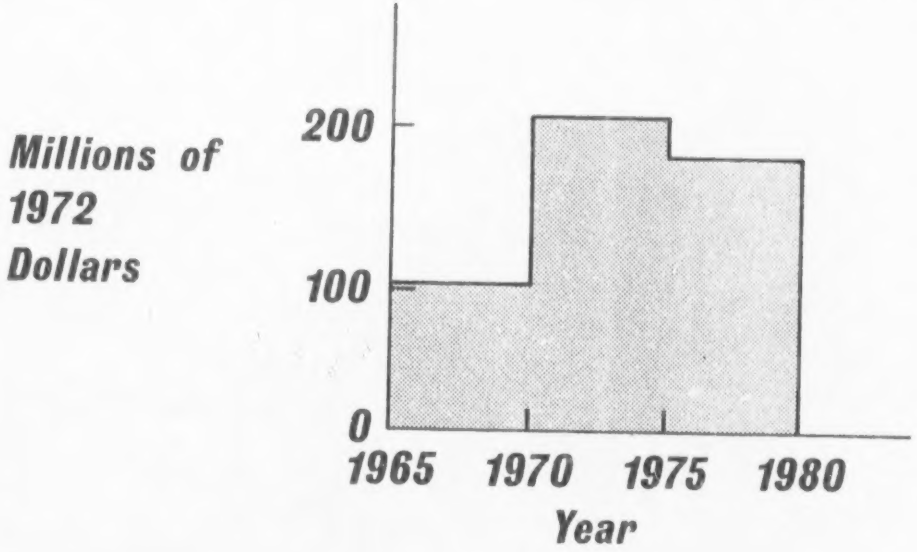


Exhibit 1

DECLINE IN CEMENT COMPANY RESEARCH FACILITIES

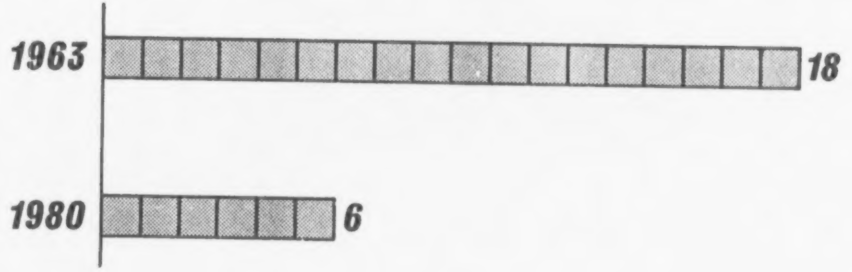


Exhibit 2

Exhibit 3 shows the decline in research expenditures by the industry through the facilities of the Portland Cement Association. Again, this reflects the extremely low profitability for most all cement companies.

I should point out, too, that in both cases here we are talking about *all* kinds of research. The work devoted to highway-related subjects would constitute only about 25% of the total.

Thus far, I have alluded to the *economic* deterrents to higher levels of cement research. There are also *structural* deterrents. For example:

1. It is traditional for public construction contracts to be awarded to the low bidder. While this practice historically has been considered necessary to the public interest, the universal application of the low-first-cost concept is a serious deterrent to new product development, quality improvement, and innovative technology. In construction, as in most activities, quality demands a premium.
2. Cement is actually a commodity, and every manufacturer makes essentially the same product. For this reason, new developments in cement or concrete technology cannot be proprietary--they must be disclosed openly so that public agencies can include them in product specifications which must be followed by all competitive bidders. This is a further deterrent to materials

AVERAGE ANNUAL RESEARCH EXPENDITURES BY PCA

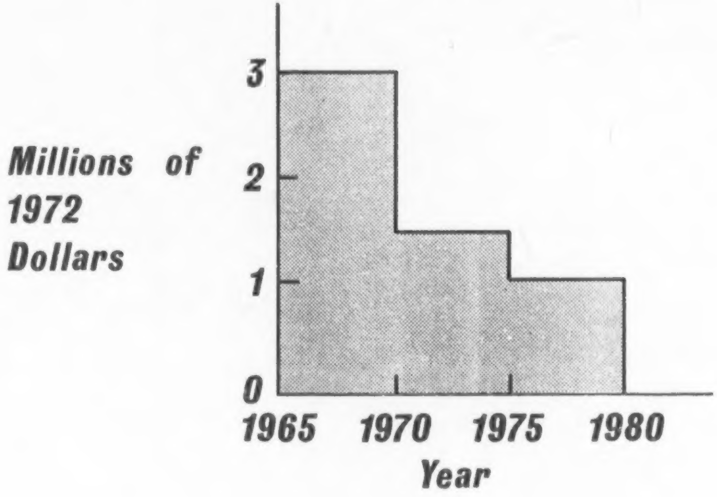


Exhibit 3

research by individual companies because the benefits of innovation are so difficult for the innovator to capture.

3. A third major structural deterrent is the one I alluded to earlier. It is the owner of the highway or bridge--in other words, the American taxpayer--that is the major beneficiary of new developments--not the cement producer. The cement producer, because the benefits are not quantifiable over the short term, has little incentive to invest heavily in the type of proprietary research that is the lifeblood of companies in other industries that make high-technology proprietary products.

Next, I would like to comment briefly on what we can expect from higher levels of research in construction materials. To do so, let me refer first to a popular misconception regarding the present poor condition of America's highways and bridges. There are some who attribute our present problems to a lack of sufficient research or to poor design and construction.

Would more research in the past have prevented all the problems we have today? Possibly, but not likely. The reason our highways and bridges are in need of repair today is that:

1. Most of the Interstate System has simply outlived its 20-year design life. That's as long as it was supposed to last. It was expected to need renovation.

2. In addition, traffic volume on many Interstate routes is three to four times greater than anticipated when these highways were built.
3. Finally, permissible vehicle weights have increased in the past two decades which shortens the useful life of highways designed to carry lighter loads.

The wonder is not that our highways are in need of rehabilitation but that they're still performing as well as they are.

Having said that, let me emphasize that more intensive research can produce dramatic benefits. I will cite just one example:

Nearly all structural concrete contains steel reinforcement in some form. High-strength steel reinforcement was being used in buildings in the early 1960's. But there had not been any research to show that this steel would stand up under the moving traffic loads on bridges. Therefore, in the early 1960's this steel could not be used in bridge construction.

In 1971, the Portland Cement Association and the federal government cooperated on a cost-sharing basis to develop the needed information. Now, as a result of that research, all reinforced concrete bridges can be built with high-strength at a 30% lower reinforcing cost. Translated into dollar savings, this means that taxpayers are saving at least $30 million to $50 million each year in this one item. This represents a research payback of $100 in savings for every dollar originally invested in the research.

Future research may offer even greater potential. For example:

1. Specialty cements now under development will make it possible to make pavement repairs or to place new overlays that can be back in service in 15 minutes and yet can last longer than the 50 years the George Washington Parkway has been in service. Such a development can greatly speed highway construction and repair, lower maintenance costs, and sharply reduce the annual cost of such highways.
2. Modern high-strength concretes for bridges are being developed in research laboratories. With proper additional research, these materials can result in greatly reduced costs and in nearly maintenance-free bridges.
3. Composite materials such as fiberglass reinforced concrete also have enormous potential for such applications as bridge deck surfaces.

It is evident, then, that public agencies--and this means the taxpayers and highway users in the final analysis--can expect large dollar paybacks from accelerated research in highway and bridge materials and construction. The question remains: How and by whom will this research be carried out?

One approach--and it's one I don't relish--is to rely on other nations for the needed research and technology--just as we have surrendered technological leadership in other industries. Or we can take the necessary steps to put our nation back on track in this important area. We suggest the latter course is the only rational approach and we recommend the following specific steps:

1. That public agencies, as the primary beneficiaries of research in highway materials and as agents for the American taxpayer, increase their participation with private industry--on a cost-sharing basis--in research into better, more economical ways to build highway pavements and bridges.
2. That more emphasis be placed on durability and quality of construction. The change in emphasis would provide added incentive for materials producers to invest more in research.
3. That a larger share of present Highway Planning and Research Funds go into research. We understand that of the 1.5% of federal highway expenditures earmarked for HPR purposes, less than one-quarter of such funds are funneled into materials-related research, while the remainder is allocated for a wide range of activities under the general heading of "Planning."

4. Finally, more extensive use should be made of the research capabilities of private industry--such as these facilities (Exhibit 4) and the excellent staff of the Portland Cement Association and other organizations representing materials interests.

If there was ever an opportunity to develop an efficient and productive partnership between government and industry on an important national issue, this certainly is such an occasion. On behalf of the U.S. cement industry, I pledge our continuing interest and cooperation toward that end and I thank you for this opportunity to present our views.

PCA R&D CENTER

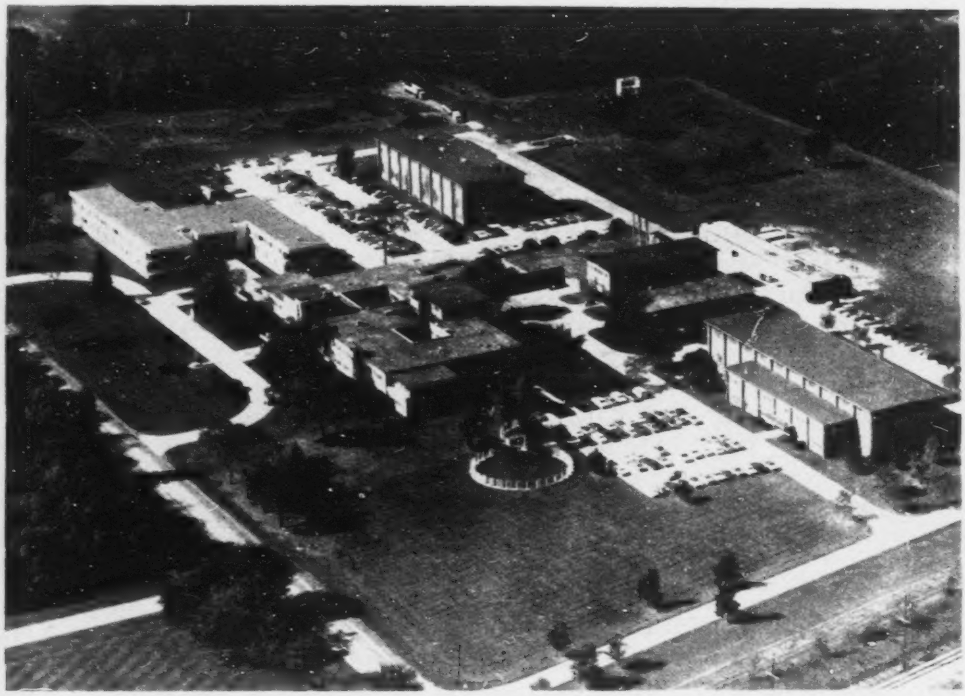


Exhibit 4

Mr. GLICKMAN. Just before we continue, what is your annual budget of your research facility?

Mr. YOUNG. The annual budget of our research facility, as supported by members' dues, at the present time is $1.8 million. In addition to that, we are doing about $5 million a year in contract research, where we go out on a bid basis and win a contract to do work for the Government or private industry.

Mr. GLICKMAN. Thank you.

Mr. Triplett, again, you may feel free to summarize your statement.

Mr. TRIPLETT. Thank you, Mr. Chairman.

The Asphalt Institute is an international nonprofit association with our research center located on the campus of the University of Maryland. We represent more than two-thirds of the Nation's production of asphalt and three-fourths of that total is used for paving. Over 94 percent of all paved roads are surfaced with asphalt mixtures or treatments. This vast production and usage places an obligation and responsibility on the industry and the Institute to provide guidelines for the sound and economical use of the material.

Successful pavement depends on adequate planning and design, on proper construction operations, and on an adequate postconstruction pavement maintenance program. Compositionally, an asphalt pavement consists of mineral aggregate, asphalt cement, and air voides. The pavement's properties, response to stresses, and service life depend on the properties and proportions of these components.

Before discussing status and trends in research on asphaltic materials, it seems appropriate to consider briefly the factors affecting pavement construction and performance.

There are seven major factors: pavement foundation, structural design, selection and properties of construction materials, paving mixture composition, construction practices, traffic intensity, and environmental conditions.

Some of these can be controlled either completely or partially by the roadbuilder. Environmental conditions are uncontrollable. The construction materials are only partially controllable. Construction practices may be classified as controllable.

The intent of these comments is to emphasize the point that satisfactory pavements depend on a multitude of factors, and this should be viewed as background.

The amount of research in asphalt pavement technology since the first asphalt pavement is voluminous. It can be separated in several areas: the development and improvements of materials, tests, and specifications, compositional design of paving mixtures, and structural thickness design procedures.

In the area of materials, a variety of asphalt types were developed. Different additives, such as various elastomers and adhesion promoters, were evaluated and some are being used. A number of inorganic or mineral additives have been tried. Hydrated lime and fly ash are some of the natural and industrial waste materials that have been evaluated and are routinely being used.

Improvements in tests and specifications of asphaltic materials were extensive. Current specifications include a measure of asphalt response to changes in temperatures.

So much for the past. What about the future? Without setting any priorities, several general areas of possibly fruitful research may be enumerated. Very likely the major part of future highway funds and efforts will be expended for the improvement or for maintenance of existing pavements. Thus, research should be directed to rationalize and make these efforts more cost effective.

While procedures for overlaying such pavements are available, research to improve and verify the design methodology would be beneficial. The standardization for procedures for evaluation of existing pavements may also be beneficial. Construction methods, techniques, and equipment utilizing pavement overlays may be beneficial.

In some other instances, pavements may require only the restoration of a safe riding surface. A variety of treatments are available. However, a research activity to improve and streamline or even to develop new procedures would be fruitful.

Management systems to schedule pavement maintenance in a timely and effective manner are currently being developed and in some instances implemented around the country. They need to be expanded and data should be gathered on the cost effectiveness and viability of various procedures.

The preparation of paving mixtures by drum processes, a relatively new technology, is exhibiting a substantial and sustained growth. A number of questions concerned with this process are presently unanswered. Research in this may lead to improvements and possibly prevent premature failures and unsatisfactory pavement performance.

Sources of crude petroleum, a parent material for asphalt, are changing. Because of this change, asphalts often are blamed for unpredicted performance, regardless of the fact that they meet specification requirements. Research is needed to resolve this controversy.

Another possibly promising research endeavor involves studies and evaluation aimed to the improvement of railway track beds for carrying heavy loads or in areas of poor soil conditions. The benefits of asphalt use in lowering rail-bed maintenance and construction costs are quite promising.

Bridge deck pavements are subjected to severe and intense demands by traffic and environment. Comparatively faster deterioration of bridge deck pavements than of the adjacent road pavements is evident. Thus, the compositional characteristics of paving mixtures when used for bridge pavements should be studied.

In closing, I would like to say that the previously discussed research areas can be classified as applied and practical. To achieve positive results in such research, the actual pavement, from its construction and through at least its initial service period, should be used as a primary site for various evaluations, supplemented when needed with basic and fundamental laboratory evaluations.

Well-planned and well-executed research would be sterile and useless if its findings were not implemented. To that effect, the industry, user and producer alike, should continuously strive to transfer and apply research findings and newly developed technology.

Assigning research priorities is another problem which should be urgently addressed. Perhaps an effective way would be to establish a task force on priorities and dissemination of research. This task force, constituted from technical representatives from industry, academia, and trade groups, could act as an adviser to agencies dealing with the establishment and apportionment of research funds.

Thank you, Mr. Chairman, for the opportunity to be here.

[The prepared statement of Mr. Triplett follows:]

Testimony by The Asphalt Institute President G. S. Triplett on Problems of and Properties for Research in Transportation Infrastructure before Subcommittees on Investigations and Oversight and on Transportation, Aviation and Materials of the U.S. House of Representatives Science and Technology Committee

INTRODUCTION

My name is Gerald S. Triplett. I am President of The Asphalt Institute. I was appointed to this presidency on March 14th of this year. Although relatively new in this position, I have served nearly twenty years as District Engineer and as Divisional and Regional Managing Engineer of The Asphalt Institute.

The Asphalt Institute is an international non-profit association representing 53 member companies that refine asphalt products from crude petroleum. The Institute's main objective is to advance the efficient and safe use of asphalt through programs of engineering, research and education. The Asphalt Institute is recognized the world over as industry's spokesman and engineering authority serving both users and producers of asphalt materials. The Institute, in its endeavors, cooperates with Federal and State agencies and with agencies representing the private industry sector.

ASPHALT USE

In 1982, approximately 26 million tons of asphalt were produced and used in the United States. Asphalt Institute members represent more than two-thirds of that production. More than three-fourths of the total asphalt produced is used for various paving purposes. It is used on interstate, primary and secondary, farm-to-market roads and city streets.

More than 94 percent of all paved roads and streets are surfaced with paving mixture or with surface treatments containing asphalt. This vast production and usage places an obligation and responsibility on the industry and The Asphalt Institute to provide guidelines for the sound and economical use of the material.

PAVEMENT DEFINED

The successful pavement depends on adequate planning and design, on proper construction operations leading to the achievement of design requirements and on an adequate post-construction pavement maintenance program. The builder and owner have to attend to these important elements to ensure satisfactory pavement performance during its years of service.

Compositionally, an asphalt concrete pavement consists of graded or sized mineral aggregate and filler, asphalt cement as a binder and air voids. Mineral aggregates are by far the largest component, comprising about 94 percent by weight or 82 percent by volume of the pavement layer. Asphalt binder, comprising approximately 6 percent by weight or 14 percent of pavement volume, can be considered a lesser component of the paving mixture. Air voids, on average, occupy between three to eight percent of the asphalt pavement volume. The pavement's properties, its response to stresses and its service life depend on the properties and proportions of all three components.

PAVEMENT PERFORMANCE

Before discussing status and trends in research on asphaltic materials it seems appropriate to consider briefly the factors affecting pavement construction and performance.

The design and performance of asphalt pavement is influenced by seven major factors: pavement foundation or subgrade soil, structural design and thickness, selection and properties of construction materials, paving mixture composition, construction practices, traffic intensity, and environmental conditions.

Some of these factors can be controlled either completely or partially by the road builder, while other factors are not controllable. The environmental conditions, subgrade properties and traffic intensity are uncontrollable. The construction materials, asphalts and mineral aggregates, are only partially controllable. The best-suited materials that are readily and economically available have to be used in a paving mixture. Often these may need altering to some extent--gravels may have to be crushed and mineral aggregates sized to meet specified criteria. Also, harder or softer asphalts, normally available in a given area, may be selected for use. The composition of the paving mixture, structural design and construction practices may be classified as controllable factors influencing pavement performance. However, it should be noted, that these latter factors are often influenced not only by engineering but also by economic considerations.

The influence of all the above factors must be carefully assessed by the builder when designing and constructing a pavement. The selection of controllable factors (materials, compositional and structural design, and construction practices) must take account of the necessity of obtaining a satisfactory response by the pavement when it is placed on a given subgrade and subjected to stresses imposed by both traffic and variations in environmental conditions.

If one or more requirements of the controllable factors are not met, this may lead to poor pavement performance or even its failure. Pavement cracking, excessive deformation and displacement, shoving and rutting, potholing, loss of surface aggregate or binder matrix are some of the symptoms indicating poor pavement performance due to inadequacy of materials, inadequate paving mixture or pavement design, and poor construction practices.

The intent of the above discussion is to underline and emphasize the point that satisfactory pavement performance depends on a multitude of factors and that interplay between these factors must be considered and balanced out when successfully designing and building top quality asphalt pavements. Also, this brief description of important influences should be viewed as background information when reviewing past and current research and considering the needs for the future research in asphalt paving technology.

PAST RESEARCH

The amount of research in asphalt pavement technology conducted since the construction of the first asphalt pavement in the 1980's, is indeed very voluminous. This may be easily ascertained by cursory but chronological review of research projects and publications issued by agencies such as Transportation Research Board (TRB), Federal Highway Administration (FHWA), The Asphalt Institute (TAI), Association of Paving Technologists (AAPT), American Society for Testing and Materials (ASTM), American Society of Civil Engineers (ASCE), American Chemical Society (ACS), and others.

In broad terms, past research and technological advances in the field of asphalt pavements may be separated into several general areas: (1) The development and improvements of materials, (2) Tests and specifications, (3) Compositional design of paving mixtures and (4) Structural thickness design procedures. The efforts and progress in these areas continued simultaneously and, it is interesting to note, that generally the volume or the number of research projects tended to grow with the growing mileage of paved roads and with the increasing volume of materials used.

In the area of materials, a variety of asphalt types, to be applied under different construction conditions in pavements or surfacings exposed to different environments and traffic loadings were developed. Asphalt cements, cutback and emulsified asphalts were such materials. Different additives, such as various elastomers, antistrip or adhesion promoters, durability and workability improvers, all were evaluated and some are currently being used. Also, a number of inorganic or mineral additives have been introduced and tried in asphalt pavements. Hydrated lime, sulphur, flyash, clays and other natural or industrial waste materials have been evaluated and, again, some are routinely being used.

Improvements in tests and specifications of asphaltic materials, binders and paving mixtures, were extensive. The progress from crude chewing tests or penetration tests to viscosity measurements span a period of about three quarters of a century. Improvements in type and specification requirements were also noteworthy. Current specifications, which are based on a fundamental viscosity measurement, also include a measure of asphalt response to changes in temperature and exposure to heating. Unfortunately, the industry still has to cope with an undesirable and costly proliferation in asphalt specifications.

The compositional design of paving mixture as used today by a majority of agencies is still based on empirical and subjective tests. However, improvements are underway through research accomplished at various university, Asphalt Institute and FHWA laboratories. More rational test methods, which were based on the fundamental measure of elastic and viscous response of paving mixtures when subjected to strains and stresses through the temperature span representing those of pavement construction and service, have been developed and are being used.

Great progress was also made in structural pavement thickness design methodology. From purely empirical "rule of thumb" methods, the structural pavement design was placed on more rational or analytical basis. Influences of climatic conditions, subgrade support, pavement material properties, and traffic loadings were assessed and considered in unifying thickness design methods. The findings accumulated at an extensive AASHTO Test Road in Ottawa, Illinois and in a number of follow-up satellite test roads contributed greatly to these structural pavement design improvements.

FUTURE RESEARCH

So much for the past. What about the future? Since many factors come into play, the discussion of future research trends in asphaltic materials and pavements involves a certain amount of speculation. However, without setting any priorities, several general areas of possibly fruitful research may be enumerated. Again, these areas deal with the improvement of materials, design procedures and construction practices -- all are vital aspects influencing a successful asphalt pavement.

1. Improvement and Maintenance

Very likely, the major part of future highway funds and effort will be expended for the improvement or for maintenance of the existing pavements. Thus, extensive research should be directed to rationalize these efforts to render them to be more cost effective. Several following fruitful research avenues may be suggested in this regard:

a. Overlays

Some pavements may require structural strengthening because of its stressed condition or because of the need to meet the demands of the ever increasing vehicular traffic. Although procedures for overlaying such pavements are available, research to improve and verify the design methodology for such overlays may be beneficial.

The standardization of procedures for the systematic evaluation of loading capacity or support value of existing pavements may also prove beneficial. In view of an increase in the allowable pavement loads and of truck-trailer configurations such information is vital to provide the input for the rational and cost effective design of pavement overlays.

The evaluation of methods, techniques and equipment utilized in construction of pavement overlays may also lead to beneficial research results.

b. Surface Treatments

In some other instances, pavements may require only the restoration of a safe riding surface. Pavement surfaces may require protection from progressive deterioration or aging without the need for the structural improvement. A variety of surface treatments are available for these purposes. However, a research activity to improve and streamline these techniques or even to develop new procedures may be prudent and fruitful.

c. Recycling

In cases where complete or practical pavement reconstruction is needed, the recycling of old pavement should be considered. Newly-developed hot and cold recycling processes and methods should be researched further to improve the compositional design of the mixture and to streamline construction techniques and construction equipment. Evaluations need to be performed on the structural equivalency, durability, and feasibility of using recycled mixes for particular projects. This research presents difficult challenges, but also offers potentially great rewards to both researcher and road builder.

d. Pavement Maintenance Management Systems

Management systems to schedule pavement maintenance in a timely and effective manner are currently being developed and in some instances are being implemented around the country. This implementation needs to be expanded. Additionally, data should be gathered on the cost effectiveness and viability of various pavement maintenance procedures. This data must then be incorporated into useable pavement management schemes that can be utilized to maximize pavement performance.

2. Evaluation of Drum Mixing

The preparation of paving mixtures by the drum process, a relatively new technology, is exhibiting a substantial and sustained growth. However, a number of questions concerned with this process are at present unanswered. This process often results in paving mixtures containing more water than those produced in the conventional hot-mix plants. Drum mixing and coating process may involve at least a partial foaming of asphalt binder before it is distributed and deposited on mineral surfaces. Also, the effects on asphalt properties when directly contacted with the burner flame and the effects of unburned fuel remain unknown. Thus, thorough evaluation of this process and the assessment of performance of drum mixes are needed. This may lead to improvements in this expdient process and, possibly prevent premature failures and unsatisfactory pavement performance.

3. Asphalt Properties, Additives and Performance

Sources of crude petroleum, a parent material for asphalt, are changing. Because of this change, asphalts often are blamed for unpredicted performance, regardless of the fact that they meet specification requirements. Research is needed to resolve this controversy. Such research could provide a valuable information on the effectiveness of different-source asphalts with mineral aggregates of different origins. Additionally, this research could be utilized to assess the effectiveness of different additives in different asphalt-aggregate systems. The cost-effectiveness of adhesion promoters, thickening agents or other additive materials could be conveniently evaluated in this research. Such evaluation could eliminate the indiscriminate use of additives by pointing out conditions where the use of such additives are unjustified.

4. Rail Transport

Another, possibly promising, research endeavor revolves studies and evaluation aimed to the improvement of railway track beds for carrying heavy loads or in areas of poor soil conditions. The costs of maintenance of rail bed ballast or its foundation constitutes a major expenditure by the rail transportation industry. The benefits of asphalt use in lowering rail-bed maintenance and construction costs are quite promising.

5. Bridge-Deck Paving

Bridge pavements are subjected to severe and intense demands by traffic and environment. Comparatively faster deterioration of bridge-deck pavements than of the adjacent road pavements is evident. Thus, the compositional characteristics of paving mixtures when used for bridge pavements have to be altered to provide an optimum response to these stresses. It is also likely that such mixtures would benefit from the use of well-selected additives. Research in this regard could reap tangible benefits.

CLOSURE

The above enumerated and discussed research areas can be classified as applied and practical research. To achieve positive results in such research, the actual pavement, from its construction and through at least its initial service period, should be used as a primary site for various evaluations. However, when needed, this applied research should be supplemented with basic and fundamental laboratory evaluations. For example, a laboratory study of the wetting and adhesion of various asphaltic binders to different mineral aggregates may be one of the promising areas for basic research. A study of binder chemical composition on its cohesive and adhesive properties is another area where laboratory evaluation can be utilized to supplement and elucidate findings of applied research.

Well planned and executed research would be sterile and useless if its findings were not implemented or applied under actual, real-life environmental conditions. To that effect, the industry - user and producer alike - should continuously strive to transfer and apply research findings and newly-developed technology. Such technology transfer and interchange is the only way to capitalize on research findings.

Assigning research priorities is another problem which should be urgently addressed by the industry. How can this be accomplished? Perhaps an effective way to address this question would be to establish a Task Force on priorities and dissemination of pavement research. This Task Force, constituted from technical representatives of users and producers, could act as an advisor to government agencies dealing with the establishment and apportionment of research funds.

Mr. Glickman. Thank you.

Dr. Smith?

Dr. Smith. Thank you, Mr. Chairman. It is a pleasure for me to be here, and an honor. It is also my first time before such a committee, so I appreciate being on the last panel so I could get a feel for what was going on.

Mr. Glickman. You feel you got experience in listening.

Dr. Smith. Oh, I certainly did.

I suppose we all saw the picture on the front page of the Washington Post today, with President Reagan sitting in a classroom. That sort of sums up my message. I want to emphasize the needed training and education aspects of the highway construction industry.

Mr. Glickman. You weren't inferring that you think the President ought to go back to elementary school, were you? [Laughter.] You don't have to answer that.

Dr. Smith. I have been engaged in transportation research for about 20 years. I am a civil engineer and I have been working primarily in the materials area. I began at Penn State University for 8 years—in fact, I started out working under Dr. Larson, who testified here yesterday, the Secretary of DOT for Pennsylvania.

During the 8 years I was there, I was engaged primarily in hot mix asphalt research through funds sponsored by the Federal Highway Administration through HP&R funds. It is true what Dr. Wootan referred to on the previous panel, that those funds did, in fact, dry up as inflation took over the dollar, and there is about a 10- to 15-year period in which there were no more people like me being trained. I know what I know today principally because of HP&R money that was made available through the university by Pennsylvania DOT.

I then left and went to work for the Federal Highway Administration here in Langley, Va. I was there for about 5 years and I did the same thing. I conducted research through FHWA staff efforts and I monitored research, such as the FHWA contract research, the NCHRP programs, and the HP&R studies. The staff research at the Fairbanks Research Facility had been greatly curtailed while I was there.

During the time I was there I noticed a general decline in the quality of reports that were being received from the HP&R program. I think this was in part because the States, feeling the austerity punch, had started to set up phantom studies more or less to just pay the salaries of engineers who were needed to do the basic functions of the highway department. In fact, the responsibilities for some of these studies were delegated down to the FHWA regional and divisional offices and we lost central control of the efforts of a lot of these programs.

From FHWA I left and went to work in my present position, where I am director of R&D for the National Asphalt Pavement Association, an association of hot mix contractors who produce hot mix asphalt. We produce between 300 to 400 million tons of hot mix a year, of which our membership produces about 75 percent of that.

I am the total R&D staff at the National Asphalt Pavement Association. I get an annual budget of about $125,000, which I must tell you I have to use very wisely.

With the increase in the tax essentially going from 4 to 8 cents, I guess it is reasonable to assume that the amount of HP&R money is now going to increase. I noted in Dr. Cole's report he anticipates it going from about $92 million to $150 million. I would anticipate some of this again would spill over into the universities as the highway departments are just totally incapable of spending that money on research in any one big surge.

I would not like to see, personally, all this money go into universities. I recognize the need for some to go there, but I would think it would be a terrible mistake to let it all go there.

Most of the research that comes from universities—and I was guilty of this. My thesis was probably only read by my dissertation committee. What it did, though, it did provide me with an opportunity to learn something that was not taught anywhere. In college, for example, for my civil engineering degree, out of 135 credits, I received 2 credits on materials technology in both portland cement and asphalt concrete. So it is essentially a learning process, and I built upon what I learned. But the results I produced were essentially worthless to anybody else.

I think this is what would happen if you let the money go to the universities. Most of the reports are measured in inches of thickness and pounds. Most people won't even bother to read them.

A lot of these reports are finally broken down and given in technical papers, such as ASTM, TRB, the Association of Asphalt Paving Technologists. Contractors don't read those. Contractors don't even attend those meetings, and these are the people who are putting down that 300 to 400 million tons of mix each year.

Now, what I am suggesting is that, instead of all this money going through the universities, at least for the time being, that it be directed to an extensive training and education program. I would have to say—I wish Mr. Gore was here. I heard him allude to a problem with opengraded friction course in Tennessee. While I was with the Federal Highway Administration I developed the design procedure for opengraded friction course, and while I was an engineer with the Federal Highway Administration I analyzed the mix failure that occurred on Interstate 40 in Tennessee. The cause of that failure was a mix design built to insuffcent standards. It had nothing to do directly with the opengraded friction course. This misinformation has now spread to the other States in the area and I think what is happening is the taxpayer is being denied an excellent skid-resistent surface.

You can travel around the Beltway near the Cabin John Bridge and it is paved with opengraded friction course, not precisely designed according to the standards that I set up, but it's there. It is overlayed over a section of road that I believe the Wright Commission made a motion picture of one time showing automobiles sliding down embankments. This is when the big Federal effort began on skid resistance.

We need a lot of training, and at NAPA that is partly my job. In fact, I have been becoming reeducated over the years and not writing thick reports any more. These are the type of reports we are writing now. [Indicating.]

Mr. **Glickman**. I can't see

Dr. **Smith**. Well, they're just thin. The idea was to show you the thickness.

Mr. **Glickman**. But what does it say, or are you just using this——

Dr. **Smith**. I am using this as an example. I will leave them here for you.

We attack specific problems on pavement performance and other things like preventing fires and explosions in asphalt plants. We have promotional articles on recycling. We do these types of things, and these are the types of documents that we do for reseach efforts that maybe only account for $5,000 total, including printing costs.

I develop training aids. Training aids are just not generally available except through our organization and through the Asphalt Institute. In fact, sometimes we get together and we do a joint training aid. This is one on rolling and compaction [indicating]. You could have all the finest engineers in the world do a beautiful mix design, select the most perfect materials, have a perfect pavement thickness, and that man sitting on top of that roller will louse it up. We're talking now about pavements that are virtually destroyed before the contractor gets to the other end of the job.

We had one case in Kansas, an Interstate pavement. Two lanes were paved. They turned around to pave the other side, the other two lanes, and the pavement was already rutting on the other side. They were going to continue with the same mix. Extensive reports were done and it all boiled down to inadequate mix design.

Here is another example of a publication—and the universities would never use this—but this is a comic book. I have to break technology down into the type of things we can get people to read. This one here is designed for the roller operator. I would suggest there is more information in this comic book about pavement compaction than the graduate engineer will have in his head when he gets out of college. He is the man the highway department sends out to do the inspection work on multimillion-dollar jobs. My first suggestion would be to equip every "job johnny" with one of these, where he could read it in about 20 minutes and become educated.

We also put on mix design schools. I call this my "Advanced Betty Crocker Course." This is a 1-week program, essentially worth 5 college credits. We are bringing our members in to teach them the concepts of mix design so that they can defend themselves. Typically in many States, highway department engineers do all the mix designs, so we are trying to tell our people, if the highway department does the mix design, or it approves them, that they should know what it is that they are going to build with.

We use a very high instruction to student ratio—four instructors to a maximum of 20 to 24 students. It costs us a $1,000 to do that per student, not counting their room and board. If I had $1 million of the available $150 million HP&R funds, we could train 500 materials engineers. We would do far more good, with the immediate research money that is going to be spent on our highways in the next 4 years, than anything that I have heard here today.

The last thing I want to mention briefly is about railroads. We are attempting to initiate a marketing program to sell asphalt to the railroads. I mean, that is our main goal, to sell asphalt. But at the same time we are trying to provide a better track structure. Obviously, if we can't do that, the railroads won't accept it. I have a series of pictures here that I will leave for you to examine. This happens to be a asphalt installation that we built and paid for in Kentucky, in conjuction with the University of Kentucky. Dr. Jerry Rose has been working with us very closely. As a matter of fact, tomorrow we are going to build another one, about 40 miles south of Lexington on a 60-mile-an-hour rail line, 32 million gross tons per year.

Now, this can benefit highways through a backdoor approach. If we can't get Congress to limit the weight limit on trucks and their size, what we can do is make it so economical to ship trucks piggyback on railroads that the trucking industry will take the trucks off the highways themselves. In fact, there are a great number of truck loading and unloading facilities that are now planned by some of the railroads. Getting some of those heavy trucks off the highways, again, would do more to extend the life of our pavements than anything we can do in research in the next 50 years.

So, with that, I will end. Thank you very much for your time.

[The prepared statement of Dr. Smith follows:]

TESTIMONY OF
RICHARD W. SMITH, PhD
DIRECTOR OF RESEARCH AND DEVELOPMENT
FOR THE
NATIONAL ASPHALT PAVEMENT ASSOCIATION
AT THE HEARINGS ON
THE PROSPECTS FOR TRANSPORTATION INFRASTRUCTURE RESEARCH
BEFORE THE
SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHTS
AND THE
SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS
OF THE
COMMITTEE ON PUBLIC WORKS AND TRANSPORTATION
OF THE
U.S. HOUSE OF REPRESENTATIVES
JUNE 15, 1983

Mr. Chairman, I am Richard W. Smith, Director of Research and Development, of the National Asphalt Pavement Association (NAPA), headquartered in Riverdale, Maryland. NAPA is the national trade association representing the owners and operators of Hot Mix Asphalt production facilities. Hot Mix Asphalt is the first choice in pavement construction for our nation's highways, airport runways and taxiways, parking lots, and thousands of other uses ranging from recreational to environmental. We sincerely appreciate the opportunity to address the combined subcommittees today on the prospects for transportation infrastructure research.

Most of you gentlemen here today are aware of the condition of our nation's infrastructure and the concern raised over the need for renewal of all our public works facilities. Members and Staff of the National Asphalt Pavement Association have been extremely active in efforts to focus attention on the need for renewing these facilities and have, on several occasions, testified to that effect before several of the Congressional committees.

The Asphalt Institute is also joining us today in presenting testimony on a number of areas where research is needed as regards product manufacture. We support their comments and would like to broaden the scope of our comments to include several other areas of interest.

Solving the problems associated with the renewal of America's infrastructure is going to require innovation: present methods, present materials, present funding mechanisms will not get the job done.

The Hot Mix Asphalt Industry has made great strides in the past few years in producing a product of the highest quality in facilities equipped with the latest technological developments, but we are being asked to do even more . . . to produce a stronger and more durable product, yet one that costs less in place.

Under current federal law, some federally funded research programs are maintained, including the mandate that at least one percent of all federal-aid highway funds distributed to the states be employed in highway-related research. Unfortunately, Mr. Chairman, we are of the opinion that while the best of results are intended, many times the final results fall far short.

When research is mentioned, the immediate thought occurs that what is intended is the kind conducted at the university level as a part of doctoral training, or some other "white coat" atmosphere situations, most of which are far removed from what is occuring out on the street. While some of this research may prove fruitful, I would not like to see the direction of these hearings result in the creation or expansion of funding for so-called research at the masters and doctoral levels. It has been my experience that such programs, although intended as research, have been used almost exclusively and necessarily for training for advanced degrees.

My suggestion would be that we focus more of our resources on education and training at the field level -- where the actual work is in progress and where we can most directly influence and educate the men and women actively involved in our rebuilding efforts. Let me say, Mr. Chairman, that there is good reason for this statement.

The National Asphalt Pavement Association has long and detailed experience in providing education and training for the asphalt paving industry. We offer continuous programs of workshops and seminars that are developed in response to the technical and managerial needs indicated by our membership. These workshops and seminars are usually three to five days duration, and provide what our experience has shown to be a very effective format. I suggest that the same type of program and format could effectively be applied in the orientation and training of engineering students, as well as individuals already employed by the industry and in the field.

It should be clear at this point that we place particular value on the contributions made by the practitioners of the asphalt paving industry, primarily because it is from that source that we consistently witness the best research and the most valuable innovations.

As in a great many industries, a large number of the advances made in the Hot Mix Asphalt Industry have come about because of the free enterprise system and its demand that the best product at the lowest price will find a ready market. This competitive demand will continue to fuel advancements in our industry, we feel, and we are hopeful that the results of your deliberations, Mr. Chairman, will be to foster this system and that you, and we, will work together to put our best efforts into a meaningful program of education and training.

In closing, Mr. Chairman, let me comment briefly on our thoughts on the infrastructure problem. First, let me underscore our concern that we fall into the same old trap of creating a massive new generation of programs that simply throw increased amounts of federal money in the direction of public works. More money is needed, but with reservations. Our infrastructure has reached its present state of disrepair because it was far too easy to build and not maintain, to go with what was popular and not necessarily with what was needed. In that regard, we believe that we must expeditiously complete a national inventory of infrastructure renewal needs, as is being done by the Joint Economic Committee of the Congress. Secondly, we hope that the Congress and the Administration can develop a method of compiling projected infrastructure spending within the Unified Federal Budget, in order that we might better set our priorities. Thirdly, we strongly support the development of an independent financing institution for public works; one that is jointly funded by the Federal Government and the states, and, one that will allow the governors of the fifty states to establish the funding priorities as will best meet the needs of their individual states. In regard to research, we fully and strongly support efforts of an equally independent nature.

Mr. Chairman, it is our belief that while a continuation of basic research is still needed in our industry, a greater need exists for the proper education and training for the men and women engaged in the practical aspects of producing and placing our product. We believe that the role of the federal and state governments in this endeavor should be limited; while we have in the past, and will continue in the future, to work with the Federal Highway Administration, the members of the American Association of State Highway and Transportation Officials (AASHTO), and similar groups, we feel the funding and direction of practical research should, and will, come from industry itself, stimulated by the needs and desires of the free-enterprise system.

The National Asphalt Pavement Association will continue to provide educational leadership to our industry and will continue to encourage the development of innovative techniques and technological advances that will improve our product and best meet the needs of our marketplace and our nation's transportation system.

Mr. Chairman, I would like to thank you again for the opportunity to share these thoughts with you and to offer the resources, energy and assistance of our Association and our industry to your efforts.

Mr. GLICKMAN. Thank you for your very practical orientation to these hearings. I just have a few questions.

Mr. Young, how far are we away from some of these technological improvements? For example, the common use for the specialty cements you talked about, the high-strength concretes for bridges, fiberglass-reinforced concrete. I mean, is it right away, soon, 5 years, 10 years?

Mr. YOUNG. High-strength concrete is a reality today. We are presently designing high-strength concrete particularly for use in high-rise structures. It has a strength five times the typical strength that is utilized in a highway specification, so that can be done.

As far as fiberglas-reinforced concrete is concerned, we are very close to a breakthrough there. Further research needs to be done, but it is very close to being a reality. Obviously, this has a significant potential benefit because, if you can take the steel out of a piece of concrete, you have eliminated the source of the rusting that causes so much of the bridge deck deterioration.

Mr. GLICKMAN. Let me ask Mr. Triplett. Is the Asphalt Institute concerned with or participating in research on materials intended to replace asphalt as a binder in pavement concrete? Are you trying to put yourself out of business?

Mr. TRIPLETT. Not completely. We are limited in two ways. One, our constitution, which concerns proprietary products, and the other, the size of our staff. We are limited numberwise to what we can do. We accept a few contracts, but they are very limited.

Mr. GLICKMAN. How much did you spend?

Mr. TRIPLETT. About $400,000 on our research staff and the research that we do. Our total budget is $3 million, and the vast majority of that is to support engineers out in the field in various States, to work with and disseminate information.

Mr. GLICKMAN. Just to get a little better idea, the cement industry in America—tell me just generally, Mr. Young, what kind of companies are we talking about?

Mr. YOUNG. As I indicated earlier, we are talking about 45 separate corporate entities who produce the product. The largest cement producer accounts today for about 11 percent of the total capacity.

Mr. GLICKMAN. Who is that?

Mr. YOUNG. Lone Star.

Mr. GLICKMAN. You have alluded to this, but have they made any money in the last few years?

Mr. YOUNG. Very little, very little.

Mr. GLICKMAN. Has the industry as a whole made any money in the last few years?

Mr. YOUNG. I would say, if you took the total financial results of the industry in 1981 and 1982, you would see a loss.

Mr. GLICKMAN. You have characterized both economic deterrents and structural deterrents to more cement research. If the current recovery continues and construction activity expands, will more research investments necessarily follow without significant structural changes?

Mr. YOUNG. I would suspect that if there is a general recovery in our industry there would be more willingness to fund greater research on an association basis. The factors I alluded to earlier, that the innovator gets very little of the benefit of the innovation, it slows down individual companies from doing research because they can't get much selfish benefit. However, when they join together in an association, then you can take the broader view because, as we make our product more competitive, it should make deeper inroads as a construction material over time.

Mr. GLICKMAN. Let me ask any or all of you that want to respond to this question: Would some kind of lifecycle costing for highway and bridge projects—as we heard last week, and I think maybe Mr. Young referred to indirectly today—help remove the low-first-cost deterrent to research that you mentioned?

Mr. YOUNG. I believe so, very significantly.

Mr. GLICKMAN. What do you think would have to be done to get States and local units of government to abide by that kind of change? Do you think you need to change State laws, or do they have that discretion now?

Mr. YOUNG. I think we would have to take what I would consider a more realistic view at the design stage. For instance, as I mentioned, our interstate program was designed for a 20-year life and it was designed with lower weights in mind than it is experiencing. And it was designed for lower traffic than it is experiencing.

Now, all this translates into a lower first cost, but it is very expensive over time. There is no secret in laying a pavement that will last a long, long time if you design for it. In Europe they traditionally design their highways for a 40-year life, not a 20-year life, and they get it because they put the upfront money down that is necessary to get the quality pavement to last the desired period of time.

Mr. GLICKMAN. Of course, they don't have to build nearly as many highways as we do.

Mr. YOUNG. No, but they get very heavy loads. If you look at those autobahns in Germany, for example, the truck traffic is very heavy, both numerically and by weight.

Mr. GLICKMAN. That's very interesting. The design of the highways is geared to a much longer life?

Mr. YOUNG. They tend to have a much longer time frame, about double ours.

Mr. GLICKMAN. I find a parallel—not so much with the cement manufacturers—but I find a parallel between the relationship of the construction industry and government, as I do in the defense industry and government. Government, in fact, determines the quality of the product and design criteria as well as research priorities much greater than almost any other kinds of industries that you see. Most industries, like the IBM's and 3M's, they kind of determine it themselves based upon the use. Naturally, of course, State governments are composed of elected political officials who want to get reelected; therefore, they want to repair roads as quickly as they can and want to get concrete or asphalt laid, where appropriate, as quickly as they can. I would submit that usually the people in the construction business are not as likely as perhaps other segments of our society are in dealing with design phase issues because of the whole nature of the institutional process. That is probably the reason why the Federal Government ought to take some of its money from this giant highway tax increase and plug it into some of the longer term issues, rather than just focus it on laying more concrete or asphalt down on the roads.

A quick summary. In the Department of Transportation, what priority research needs would you think ought to be pushed by our Federal Government?

Mr. **Triplett**. Maintenance, management systems, would be a top priority.

Mr. **Glickman**. Mr. Young?

Mr. **Young**. I agree very strongly with Dr. Smith's point. I think training is very, very essential toward improved quality. It is true in our product just as it is in asphalt. In other words, you can spend millions to construct a chemically sound and consistent product, you can do all kinds of research with it, and one man with one hose can ruin it in a minute. Training is important.

Dr. **Smith**. I would like to also say, in conjunction with training, we have to remove some of these arbitrary travel restrictions. I mean, when I go out and give a presentation, for example, on recycling, in a tristate area, I will give a presentation in one State and the other engineers in the other two States travel as close to the border as they can in their respective States, stay in a motel, and the next day slip over the State line to attend a meeting, because the Governor has restrictions on State employees leaving the State for training.

Or, if you have 20 materials engineers, and the 20 materials engineers want to attend a conference on new materials or new techniques for making their product better, somebody will say "we can only afford to have 2 people go", so the other 18 don't go. With these kinds of things, we're finding it very difficult to get to people and get them to come to training sessions.

Mr. **Glickman**. That would, of course, be somewhat related to the management of the State highway programs?

Dr. **Smith**. Oh, yes.

Mr. **Triplett**. The tools are available in asphalt, and I am sure they are in portland cement, also. We recently completed developing a text on training procedure for the FHWA. It is an effort to obtain attendance at these schools.

Dr. **Smith**. I would like to reemphasize what you stated about government as part of the asphalt industry. They design the pavement thickness. In many States they even do the mix design. In many States they even tell you how to build it.

Now, if it goes bad and fails—and on top of that we can add on contractor error as well—but when the pavement fails, it is our industry that gets hurt because of something we had no control over.

Mr. **Glickman**. This is an interesting question. It doesn't really relate to the subject matter of materials, but I am going to venture forth for a moment.

Why is it that there is more—and I'm phrasing this as a question—alleged and real price fixing and criminal activity occurring in the 50 States in areas of price gouging in the two areas of road construction and defense contracts? It's very curious. Am I wrong in that statement? Certainly in my State the newspapers have been full of stories for the last 3 years about a variety of road construction payoffs, civil and criminal problems involving the relationships between contractors and State and local governments. It's very curious because I think it relates to the subject we're talking about now, how roads are built and maintained. A large part is due to management and the relationship between all the parties involved.

You made that point yourself. States are designing the roads or designing the materials. In fact, there is an institutional problem which prevents modernization through the nature of the bidding process.

We may be able to do all the great research we can in the area of setting up a center for materials research, and yet nothing will be able to be implemented because of the unique nature of how we build roads in America.

Mr. YOUNG. In line with what you just said, it seems to me that we're placing tremendous emphasis on the pavement portion of the highway. If you take an interstate highway and you calculate the total cost of the highway—and by that I mean the surveying, the land condemnation, the clearing, the grading, the subbase—the surfacing is 15 percent of the total cost. That is where all this attention centers and that is why I said, if you spent a little more money on the surface in the first place, you would get a lot more durability and you wouldn't impact the overall cost hardly at all.

Mr. GLICKMAN. OK. Well, as our friends from IBM and 3M said today, you have got to deal with the real world. I think we have to deal with the real world on how roads are built and relate it back into some of the other things we were talking about here.

I am also reminded of—I think both Dr. Smith and Mr. Young referred to the fact that all the research is worthless if somebody makes a very bad mistake. I am reminded that we can spend $40 million on a Lockheed 1011, but if a mechanic forgets to put O-rings on all three engines, all that technology goes down the drain. So we have a lot of the same parallels in other industries as well.

I appreciate your testimony very much today. It is quite useful. The committee thanks you for taking the time to come down here. We have one more day of hearings tomorrow.

The hearing will stand adjourned today. Thank you.

[Whereupon, at 1 p.m., the subcommittees were adjourned.]

TRANSPORTATION INFRASTRUCTURE RESEARCH AND TECHNOLOGY

THURSDAY, JUNE 16, 1983

HOUSE OF REPRESENTATIVES, COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT, AND THE SUBCOMMITTEE ON TRANSPORTATION, AVIATION, AND MATERIALS,

Washington, D.C.

The subcommittees met in joint session, pursuant to call, at 9:35 a.m., in room 2325, Rayburn House Office Building, Hon. Dan Glickman (chairman of the Subcommittee on Transportation, Aviation, and Materials) presiding.

Mr. GLICKMAN. Good morning. Today we begin the third day of some very, very interesting hearings on the issue of highway transportation infrastructure research and technology. We have had two extraordinarily good days of hearings with the scientific community and with trade people, and today we hear from government people regarding the problem of our Nation's infrastructure, our highways and roads, which as we have stated before are rapidly deteriorating.

The typical interstate highway is designed to last 20 years before it requires major rehabilitation, and 41 percent of the interstate highway system has already reached this milestone. Forecasts indicate that by the year 1990, 75 percent of the interstate highway system will have reached the 20-year milestone, while also being subjected to traffic at a level of 150 percent of the capacity that these highways were designed to handle. Perhaps the most alarming example of the condition of our highway infrastructure is the fact that 23 percent of the Nation's bridges have been identified as structurally deficient.

Although the recently enacted Surface Transportation Act and the increased gasoline taxes will provide some increased funding for highway and bridge rehabilitation, we must also renew our commitment to the research that supports that effort. This committee has been concerned with insuring the use of improved technologies, materials, and construction methods to insure that Federal highway funds are used in the most cost-effective manner possible. We hope that this hearing today will focus on what is and should be the Federal role in determining not only that we have pumped billions of dollars into our Nation's highways and bridges throughout this country, but that we are also doing the appropriate amount of research so that those billions of dollars don't have to be replaced by additional billions of dollars 5 years down the line.

Saying that, I would now like to introduce my co-Chair, Congressman Gore of Tennessee.

Mr. **Gore**. Thank you very much, Mr. Chairman.

It is my pleasure today to join in welcoming representatives from the Department of Transportation, our last witnesses in this series of hearings. While last on the witness list, the DOT is clearly essential to any review of highway infrastructure research.

During the first 2 days of testimony, which I regarded as unusually constructive testimony, we heard about the declining state of our Nation's bridges and roads and how the collective research effort in materials and design is conducted. We have heard some praise for these efforts, but we also heard substantial criticism of the Nation's inability to focus appropriate resources—to reach a critical mass of research effort, if you will—on vital research needs, needs which, if addressed, could save billions and billions of dollars. We have also heard about some of the reasons for these research gaps and about the inadequate funding allocated to this area.

Over the past few decades DOT has funded and directed, together with the States, the building of our Nation's highway system. DOT is clearly central in any large research effort. So, as we turn away from any major road building programs to a program with primary emphasis on repair and maintenance, we will want to look closely at DOT's plans to fund, direct, organize, coordinate and develop new technologies to improve our Nation's roads and bridges.

I look forward to today's testimony.

Mr. **Glickman**. Thank you, Albert.

Without objection, the statement by Congressman Carney will be put in the record at this point.

[The prepared statement of Mr. Carney follows:]

STATEMENT FOR HON. WILLIAM CARNEY
HEARING ON TRANSPORTATION INFRASTRUCTURE R&D

JUNE 16, 1983

MR. CHAIRMAN, THE TWO DAYS OF HEARINGS ON TRANSPORTATION INFRASTRUCTURE R&D HAVE BEEN INTERESTING AND ENLIGHTENING. I'M ENCOURAGED BY THE TESTIMONY WE'VE HEARD. THERE'S BEEN REMARKABLE AGREEMENT ON THE ISSUES AMONG THE WITNESSES FROM ACADEMIA, THE PRIVATE SECTOR, AND THE STATES.

THE TESTIMONY WE'VE HEARD THESE FIRST TWO DAYS WOULD CERTAINLY LEAD US TO BELIEVE THAT THE PROBLEMS FACING US ARE NOT INSOLUBLE, AND INDEED IT WOULD APPEAR THAT WITH PROPER PLANNING AND MANAGEMENT WE COULD HAVE SUBSTANTIAL IMPROVEMENTS IN THE DURABILITY AND SAFETY OF OUR HIGHWAYS AND BRIDGES WITHOUT MASSIVE INCREASES IN THE FEDERAL BUDGET.

ON A LESS OPTIMISTIC NOTE, HOWEVER, THERE APPEARS TO BE A CONSENSUS THAT SOME FUNDAMENTAL FLAWS EXIST IN THE WAY WE FUND RESEARCH IN THIS AREA, AND EVEN IN THE WAY WE GO ABOUT BUILDING OUR HIGHWAYS AND BRIDGES. CERTAINLY, THE LOW BIDDER CONCEPT NEEDS TO BE REEXAMINED TO SEE IF THE EFFECT ISN'T CONTRARY TO ITS INTENDED PURPOSE, AND THAT IT DOESN'T ACT TO DISCOURAGE INNOVATION AND IMPROVED PRODUCT DEVELOPMENT.

I LOOK FORWARD TO HEARING THE TESTIMONY OF TODAY'S WITNESSES REPRESENTING THE DEPARTMENT OF TRANSPORTATION AND THE OFFICE OF SCIENCE AND TECHNOLOGY. CLEARLY, ALL SEGMENTS OF THE TRANSPORTATION INDUSTRY NEED TO BE WORKING TOGETHER ON THESE PROBLEMS IF WE'RE TO HAVE THE SAFETY AND CONVENIENCE IN OUR TRANSPORTATION INFRASTRUCTURE THAT WE BELIEVE THAT WE SHOULD HAVE AND THAT WE BELIEVE WE ARE NOW PAYING FOR.

THANK YOU.

Mr. Glickman. Congressman Skeen, do you have any statement?

Mr. Skeen. I have no statement, Mr. Chairman.

Mr. Glickman. Congresswoman Schneider?

Mrs. Schneider. No, thank you.

Mr. Glickman. Our first witness is Dr. Douglas Pewitt, Assistant Director for General Science, Office of Science and Technology Policy with the Executive Office of the President. We understand, Dr. Pewitt, you have a time problem, and so it is a pleasure to have you here. Your entire statement will be included in the record, so you may feel free to summarize, if you wish.

STATEMENT OF DR. N. DOUGLAS PEWITT, ASSISTANT DIRECTOR FOR GENERAL SCIENCE, OFFICE OF SCIENCE AND TECHNOLOGY, EXECUTIVE OFFICE OF THE PRESIDENT

Dr. Pewitt. Thank you, Mr. Chairman.

It is my pleasure to be here today to present the administration's views on the appropriate role of the Federal Government in basic and applied research. I will touch briefly also on that role as it applies to transportation infrastructure problems.

Let me say at the outset that the Office of Science and Technology Policy has been involved in only a limited way with transportation research. The small size of our staff limits the range of activities that we can track actively. Our involvement in transportation has been principally in the study of Federal policy for aeronautics research and technology. Dr. Victor Reis of our office has briefed Mr. Glickman's subcommittee on the outcome of that study last December. I will defer to the Department of Transportation's representatives on the details regarding transportation research.

The administration's science and technology policy aims to maintain and strengthen our science and technology base to support the advancement of national goals. This is a broader and more results-oriented approach than in the past when the focus of national science and technology policy was concerned almost solely at the health of science and its institutions. We view support for R&D as a means to an end, not an end in itself.

At the heart of the science policy is the discipline that three criteria be met. The first of these criteria is excellence—first class research, high quality researchers. Any evaluation of the state of American science and technology today clearly reveals fields of research ripe for profound intellectual advances, fields bursting with excellent ideas. Much of our effort is focused on identifying those opportunities and reallocating R&D in those areas.

A second criteria is pertinence, or the prospect of meeting a national need. Society derives two tangible benefits from Federal support of R&D. One is the transfer of knowledge from the laboratory to society. That requires stimulating greater interaction of academic, Federal and industrial scientists and engineers, and making sure the best R&D is supported well enough to permit rapid progress.

The second benefit the public derives is the educational and training advantages of R&D support, because almost all of our expectations and opportunities for the future call for a growing supply of skilled technical personnel.

The third and most controversial criterion of our science policy is the appropriateness of the Federal role. The controversy arises over interpretation of what is or is not appropriate. Our aim is to distinguish clearly between Federal and private sector responsibilities. This aspect of our policy is not born of ideology but practicality. The private sector which operates in the marketplace is far more successful than the Government in undertaking commercially oriented technology. So we have worked to shift the Federal role in civilian research and development away from demonstrations of technology. We are moving the Government toward a more appropriate role in basic research and noncommercial development areas where the Government is clearly responsible.

It is the administration's view that the Federal Government should fund R&D to meet specific Government needs, where the principal user is the Government itself—for instance, to support national defense.

Also to support national needs, where the Federal Government shares responsibility with the private sector for activities of a sort that private firms cannot realize a sufficient return to warrant individual investment.

The administration will support research activities that result in new knowledge from which commercial technology may ultimately be derived. However, it is uniquely industry's role to translate this knowledge into commercial processes and products. In addition, the Federal Government has the responsibility for insuring that it does not stifle R&D activities in the private sector through poorly designed regulations and tax policies.

The Federal Government clearly has a role in research applied to transportation infrastructure problems. For example, research and development related to improved air traffic control is an obvious responsibility which relates both to specific government needs as well as broader national needs. Last year the White House Science Council reviewed the Federal Aviation Administration's plan for modernizing the national air traffic control system. The Science Council's report to Dr. Keyworth was well received and its key recommendations are already being implemented.

Other examples of appropriate Federal roles are in basic research on corrosion mechanisms which affect bridge and highway materials, et cetera, and in the development of navigation systems.

In summary, the administration seeks to support sufficient basic and long-term nonproprietary applied research to improve our Nation's science and technology enterprise. It recognizes the need for a strong Federal role in that support. The criterion of excellence, pertinence and appropriateness continue to be central to science and technology policy. Previous policies have failed in part to recognize these criteria and have distracted the Federal Government from its major responsibility by extending Federal involvement into activities that did not satisfy the criteria. The Reagan administration has begun to refocus the Federal Government's attention on to those research areas where it has responsibility and capability.

That is the end of my statement. I would be pleased to respond to questions.

[The statement of Dr. Pewitt follows:]

TESTIMONY OF DR. N. DOUGLAS PEWITT
ASSISTANT DIRECTOR FOR GENERAL SCIENCE
OFFICE OF SCIENCE AND TECHNOLOGY
EXECUTIVE OFFICE OF THE PRESIDENT

COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT
SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS
UNITED STATES HOUSE OF REPRESENTATIVES

JUNE 16, 1983

CHAIRMAN GORE, CHAIRMAN GLICKMAN AND MEMBERS OF THE SUBCOMMITTEES:

IT'S MY PLEASURE TO BE HERE TODAY TO PRESENT THE ADMINISTRATION'S VIEWS ON THE APPROPRIATE ROLE OF THE FEDERAL GOVERNMENT IN BASIC AND APPLIED RESEARCH. I WILL ALSO TOUCH BRIEFLY ON THAT ROLE AS IT APPLIES TO TRANSPORTATION INFRASTRUCTURE PROBLEMS.

LET ME SAY AT THE OUTSET THAT THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY HAS BEEN INVOLVED IN ONLY A LIMITED WAY WITH TRANSPORTATION RESEARCH. THE SMALL NUMBER OF PROFESSIONAL STAFF MEMBERS LIMITS THE RANGE OF RESEARCH ACTIVITIES THAT WE CAN TRACK ACTIVELY. OUR INVOLVEMENT WITH TRANSPORTATION HAS BEEN PRINCIPALLY IN THE STUDY ON FEDERAL POLICY FOR AERONAUTICS RESEARCH AND TECHNOLOGY. DR. VICTOR REIS OF OUR OFFICE BRIEFED THE SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS LAST DECEMBER ON THE OUTCOME OF THAT STUDY. TODAY I WILL DEFER TO THE DEPARTMENT OF TRANSPORTATION'S REPRESENTATIVES ON MOST OF THE DETAILS REGARDING TRANSPORTATION RESEARCH.

THE ADMINISTRATION'S SCIENCE AND TECHNOLOGY POLICY SEEKS TO MAINTAIN AND STRENGTHEN OUR SCIENCE AND TECHNOLOGY BASE TO SUPPORT THE ADVANCEMENT OF NATIONAL GOALS. THIS IS A BROADER AND MORE RESULTS ORIENTED APPROACH THAN IN THE PAST WHEN THE FOCUS OF NATIONAL SCIENCE AND TECHNOLOGY POLICY WAS AIMED ALMOST SOLELY AT THE HEALTH OF SCIENCE AND ITS INSTITUTIONS. IN CONTRAST, WE VIEW SUPPORT FOR R&D AND A STRONG SCIENCE AND TECHNOLOGY BASE AS A MEANS TO AN END, NOT AN END IN ITSELF. SCIENCE, LIKE ART AND SYMPHONY ORCHESTRAS, IS A WORTHY CULTURAL PURSUIT. THIS IS WHY MOST SCIENTISTS ENTER AND STAY IN THE FIELD. BUT, THIS ALONE DOES NOT JUSTIFY THE $47 BILLION THAT THE PRESIDENT HAS PROPOSED FOR R&D IN FY 1984.

SCIENCE POLICIES THAT SERVED THE NATION WELL DURING DECADES OF RELATIVE ECONOMIC AFFLUENCE AND OVERWHELMING AMERICAN TECHNOLOGICAL SUPERIORITY OVER OTHER NATIONS MUST BE MODIFIED TO DEAL WITH TODAY'S HARSHER CONDITIONS. ALL OF US HAVE A RESPONSIBILITY TO MAKE SURE THE NATION GETS THE BEST POSSIBLE RETURN ON ITS FEDERAL INVESTMENTS IN SCIENCE AND TECHNOLOGY.

AT THE HEART OF THE SCIENCE POLICY IS THE DISCIPLINE THAT WE MUST EXERCISE IN FEDERAL FUNDING OF RESEARCH AND DEVELOPMENT. THREE CRITERIA MUST BE MET. BY APPLYING THOSE THREE CRITERIA--AND BY RESISTING THE TEMPTATION TO DIVERT LIMITED RESOURCES TO QUICK-FIXES OF SHORT TERM PROBLEMS--WE'RE CONFIDENT WE'VE ESTABLISHED PRIORITIES THAT ADDRESS U.S. NEEDS FOR THE YEARS TO COME.

THE FIRST OF THESE CRITERIA IS EXCELLENCE - FIRST CLASS RESEARCH, HIGH QUALITY RESEARCHERS. ANY EVALUATION OF THE STATE OF AMERICAN SCIENCE AND TECHNOLOGY TODAY CLEARLY REVEALS FIELDS OF RESEARCH RIPE FOR PROFOUND INTELLECTUAL ADVANCES, FIELDS BURSTING WITH EXCELLENT IDEAS AND PEOPLE. MUCH OF OUR EFFORT IS FOCUSED ON IDENTIFYING THOSE OPPORTUNITIES--AND REALLOCATING R&D RESOURCES TO THESE AREAS. WE'RE CONFIDENT THAT THESE EMPHASES REFLECT BROAD AND INFORMED CONSENSUS OF THE S&T COMMUNITY. THIS FIRST CRITERION--EXCELLENCE--OR THE OPPORTUNITY FOR SCIENTIFIC ADVANCE--GUIDES THE SELECTION OF AREAS BUDGETED FOR FASTEST GROWTH.

A SECOND CRITERION--HOW ELSE DO WE ASSURE THE BEST RETURN ON OUR INVESTMENT? HERE WE'RE TALKING ABOUT PERTINENCE, OR THE PROSPECT OF MEETING A NATIONAL NEED. SOCIETY--THAT IS, THE PEOPLE PAYING THE BILLS FOR FEDERAL PROGRAMS--DERIVE TWO TANGIBLE BENEFITS FROM R&D. ONE IS TRANSFER OF KNOWLEDGE FROM THE LABORATORY TO SOCIETY--IN THE FORM OF TECHNOLOGICAL INNOVATIONS THAT RESULT IN NEW INDUSTRIES, NEW JOBS, IMPROVEMENTS IN OUR STANDARDS OF LIVING AND QUALITY OF LIFE AND A MORE SECURE NATIONAL DEFENSE. THAT REQUIRES STIMULATING GREATER INTERACTION OF ACADEMIC, FEDERAL, AND INDUSTRIAL SCIENTISTS AND ENGINEERS, AND MAKING SURE THE BEST R&D IS SUPPORTED WELL ENOUGH TO PERMIT RAPID PROGRESS. THE SECOND BENEFIT THE PUBLIC DERIVES FROM FEDERAL R&D IS THEIR EDUCATIONAL

AND TRAINING ADVANTAGES BECAUSE ALL OF OUR EXPECTATIONS AND OPPORTUNITIES FOR A BETTER, MORE SECURE FUTURE CALL FOR A GROWING SUPPLY OF SKILLED TECHNICAL PERSONNEL. OFTEN THE MOST IMPORTANT PRODUCT OF A RESEARCH GRANT IS GRADUATE STUDENTS WHO BECOME MEMBERS OF THE RESEARCH COMMUNITY THROUGH PARTICIPATION IN FACULTY RESEARCH PROJECTS.

THE THIRD AND THE MOST CONTROVERSIAL CRITERION OF OUR SCIENCE POLICY IS THE APPROPRIATENESS OF THE ROLE OF THE FEDERAL GOVERNMENT IN R&D. THE CONTROVERSY ARISES OVER INTERPRETATION OF WHAT IS OR IS NOT APPROPRIATE. OUR AIM IS TO DISTINGUISH CLEARLY BETWEEN FEDERAL AND PRIVATE SECTOR RESPONSIBILITIES. THIS ASPECT OF OUR POLICY IS NOT BORN OF IDEOLOGY, BUT PRACTICALITY. THE PRIVATE SECTOR, WHICH OPERATES IN THE MARKETPLACE, IS FAR MORE SUCCESSFUL THAN THE GOVERNMENT IN UNDERTAKING COMMERCIALLY ORIENTED, SHORT-TERM TECHNOLOGY PROGRAMS. SO, WE'VE WORKED TO SHIFT THE FEDERAL ROLE IN CIVILIAN RESEARCH AND DEVELOPMENT AWAY FROM DEMONSTRATIONS OF TECHNOLOGY. WE'RE MOVING TOWARDS GOVERNMENT'S APPROPRIATE ROLE IN BASIC RESEARCH AND NONCOMMERCIAL DEVELOPMENT AND AREAS WHERE THE GOVERNMENT IS CLEARLY RESPONSIBLE.

IT IS THE ADMINISTRATION'S VIEW THAT THE FEDERAL GOVERNMENT SHOULD FUND R&D ACTIVITIES TO MEET:

- Specific Federal Government needs, where the principal user of the R&D is the government itself, for example, to support national defense; and
- National needs, where the Federal Government shares responsibility with the private sector. Appropriate for government funding in this category are R&D activities that improve the quality of life or support the Nation's long-term economic strength, AND are of such a nature that private firms or consortia cannot realize a sufficient return to warrant individual investment in them.

The Administration will support research activities that result in new knowledge from which commercial technology may ultimately be derived. However, it is uniquely industry's role to translate this knowledge into commercial processes and products, and to support research and technology development where necessary to complement that supported by the Federal Government. Thus, the Federal Government could support projects to identify key gaps in knowledge or to test experimental predictions. However, the Federal responsibility does not include support for commercial prototypes, demonstration models, or subsequent engineering development activities. In addition, the Federal Government has the responsibility for ensuring that it does not stifle R&D activities in the private sector through poorly designed regulations and tax policies.

THE FEDERAL GOVERNMENT CLEARLY HAS A ROLE IN RESEARCH APPLIED TO TRANSPORTATION INFRASTRUCTURE PROBLEMS. FOR EXAMPLE, R&D RELATED TO IMPROVED AIR TRAFFIC CONTROL IS AN OBVIOUS FEDERAL RESPONSIBILITY WHICH RELATES BOTH TO SPECIFIC GOVERNMENT NEEDS AS WELL AS BROADER NATIONAL NEEDS. I MIGHT NOTE THAT LAST YEAR, THE PRESIDENT'S SCIENCE ADVISOR, JAY KEYWORTH, REQUESTED THE WHITE HOUSE SCIENCE COUNCIL TO REVIEW THE FEDERAL AVIATION ADMINISTRATION'S PLAN FOR MODERNIZING THE NATIONAL AIR TRAFFIC CONTROL SYSTEM. THE SCIENCE COUNCIL'S REPORT TO DR. KEYWORTH WAS WELL RECEIVED BY THE AVIATION COMMUNITY AND TODAY IT'S KEY RECOMMENDATIONS ARE ALREADY BEING IMPLEMENTED.

OTHER EXAMPLES OF APPROPRIATE FEDERAL ROLES ARE IN BASIC RESEARCH ON CORROSION MECHANISMS WHICH AFFECT BRIDGE AND HIGHWAY MATERIALS AND IN DEVELOPMENT OF NAVIGATION SYSTEMS USING EARTH-ORBITING SATELLITES.

IN SUMMARY, THE ADMINISTRATION SEEKS TO SUPPORT SUFFICIENT BASIC AND LONG-TERM NONPROPRIETARY APPLIED RESEARCH TO IMPROVE OUR NATION'S SCIENCE AND TECHNOLOGY ENTERPRISE, AND IT RECOGNIZES THE NEED FOR A STRONG FEDERAL ROLE IN THAT SUPPORT. THE CRITERIA OF EXCELLENCE, PERTINENCE, AND APPROPRIATENESS CONTINUE TO BE CENTRAL TO SCIENCE AND TECHNOLOGY POLICY. PREVIOUS POLICIES HAVE FAILED IN PART TO RECOGNIZE THESE CRITERIA AND HAVE DISTRACTED THE FEDERAL GOVERNMENT FROM ITS MAJOR RESPONSIBILITY BY EXTENDING FEDERAL INVOLVEMENT INTO DEMONSTRATION ACTIVITIES THAT DO NOT SATISFY THE CRITERIA. THE REAGAN ADMINISTRATION HAS BEGUN TO RETURN THE FEDERAL GOVERNMENT'S ATTENTION TO THOSE RESEARCH AREAS WHERE IT HAS THE PROPER RESPONSIBILITY AND CAPABILITY.

THIS CONCLUDES MY FORMAL PRESENTATION. I WOULD BE PLEASED TO ANSWER ANY QUESTIONS FROM THE COMMITTEE.

Mr. **Glickman**. Thank you, Dr. Pewitt.

You said the Reagan administration has begun to turn the Federal Government's attention to those research areas where it has the proper responsibility and capability. You also state in your statement that transportation infrastructure is one of those areas of responsibility—and you mentioned the air traffic control situation as well.

But when you look at the facts, isn't it true that in the areas of nonexotic transportation programs, such as highways, bridges, and roads, that the level of research by the Government has just fallen virtually to nothing in the last few years?

Dr. **Pewitt**. One of the reasons that we have not concentrated in our office on transportation infrastructure problems in the main is plain and simply the level of resources that the Federal Government has dedicated in this area has been relatively small compared to the rest of the $47 billion. As I said in my opening statement, we have not tracked transportation infrastructure very closely——

Mr. **Glickman**. "We" meaning your office?

Dr. **Pewitt**. We in OSTP. We are fortunate in this one area of science and technology where there is a Cabinet department, the Department of Transportation, with principal responsibility. I am sure Secretary Dole is looking at this very carefully and how she wants to execute her responsibilities in the Department of Transportation for oversight of this research function.

It is clear to us that we're going to make massive Federal investments in transportation. I have spent some time over the last 7 months, even prior to these hearings, with the Department of Transportation, looking into their research capability. We have many questions. We don't have all the answers yet, but we have started to look into these areas. There is considerable research capability in the Department. Whether or not we can help the Secretary in this area is something that we will be determining.

It is a classic problem. We spend billions to go to Jupiter and we don't know how to repair a pothole yet. It is an obvious question of——

Mr. **Glickman**. It is also the money, to not only repair pot holes but to build roads, comes from a regressive tax. It comes out of the pockets of working people who pay whatever the Federal and State gasoline taxes are. I would just think that you, as kind of the chief coordinating role for science issues within the administration, ought to insure that you take an aggressive role in protecting the interests of those billions of dollars that are being spent to insure, one, that the roads are adequately maintained and repaired, and two, that we do the research so that we can protect ourselves against deterioration, which may be unnecessary, and three, so that we don't have to raise the gasoline taxes again in the future through more appropriate management of the existing system. R&D has to be a key part of that thing.

How do you think your office can more effectively encourage Federal departments to support appropriate basic research like in the transportation area, when Secretaries and Administrators seem only interested in short-term results?

Dr. **Pewitt**. We counsel a lot with Cabinet officials. It is not clear that we are not supporting the right sort of basic research. That is the nature of basic research. It is discipline oriented rather than end use oriented. We have a tremendous emphasis on research, and our science policy has emphasized materials research to a very significant degree. We appreciate the support that the House Science and Technology Committee has provided to some of those initiatives in materials research because ultimately transportation infrastructure is a materials problem.

In the agencies that have significant basic research activities, we have emphasized basic research, as you know.

Mr. GLICKMAN. The only question I would have would be if you are emphasizing basic research into exotic materials. About 12 years ago Dr. David, who was President Nixon's science adviser, said that research into cement and highway construction materials was at the top of the list of areas in which the greatest return on the Federal R&D dollar could be expected, but there have been virtually no Federal R&D dollars to speak of that have been expended in that area. We are spending a lot on some of the more exotic materials, which I support as well, and it just looks like there's a gap that has developed there, because folks have this kind of facination with computers and sexy kinds of stuff, and concrete is not very sexy.

I assume that you're aware of Dr. David's reports and statements, and I think politically it also makes sense for any administration to be doing the kind of research that will make the people back home happy and, clearly, having longer lasting roads makes people happy.

Dr. PEWITT. And the Reagan administration certainly does not want to be in a position of forcing an increase in taxes in the future, yes, sir.

Thank you.

Mr. Gore.

Mr. GORE. I have reviewed the statements of the administration witnesses before the hearing, and, of course, we look forward to hearing your colleagues when they come up here. But you're the first up at bat. And in some respects you are representing that part of the administration responsible for coordinating the Nation's research effort; would you agree with that?

Dr. PEWITT. One of our responsibilities is to oversee Federal R&D activities, and we provide advice within the executive offices on proposals by agencies as to the validity of those proposals, yes, sir.

Mr. GORE. Do you understand the concerns of these two subcomittees, I mean, what these hearings are all about?

Dr. PEWITT. I think I understand these concerns.

Mr. GORE. How would you state them?

Dr. PEWITT. Well, I think, plain and simply, the Federal Government has a massive capital investment in the transportaton infrastructure. Principally, highways and roads are the focus of these hearings. We are concerned, you are concerned, the committee is concerned, about whether or not we are investing enough and whether we are investing not only enough, but in the right things. For example, R&D to support bridge building, road repair, so that we are not just endlessly replacing this capital investment. A 20-year lifetime for things that cost billions and billions of dollars is not good enough. Clearly it is in everyone's interest not to build and rebuild and rebuild an infrastruture that the whole society depends on.

Moreover, I think, from a personal point of view, having looked into this area, it is not clear we know how to repair a bridge. We know how to rebuild a bridge. But you can ask yourself a lot of questions about whether we have studied this problem enough. There are an awful lot of bridges to be rebuilt. One only needs to look down the river to the Wilson Bridge to wonder if we can't do it better. We have those same questions.

Mr. GORE. We are on the verge of a massive new wave of public investment in the repairing and maintenance of this system. It is wearing out more quickly, for the reasons my cochairman stated in his opening remarks. We're going to spend ten of billions of the public's dollars on this new wave.

There are clearly opportunities to substitute thought for money. We can save lots of money if we can figure out how to do it a little bit better and extend the lifetime of these new improvements beyond what they would otherwise be.

Now, you and your colleagues at OSTP are concerned with the overall Government research policies. We have heard testimony here about the tremendous opportunities to save money by doing basic research into concrete, cement, asphalt and all of that, all these things that are relatively mundane sounding but have a tremendous potential to save the country money and to save the taxpayers money.

But the testimony has really been quite critical of the R&D policy of the administration. The statements submitted here today—and I will say this in a reserved and gentle way—the statements are a little flabby. They don't really respond directly what what I think has been a very extensive criticism from the private sector and university research community. I'm a little concerned about that.

Did you have to review your statement with anyone?

Dr. PEWITT. No.

Mr. GORE. Who did you have to get it approved by?

Dr. PEWITT. I spoke to Dr. Keyworth about the content. We are in the Executive Office, after all.

Mr. GORE. I don't fault that at all. Did you have to submit it to OMB?

Dr. PEWITT. No. We are in the Executive Office. We don't normally submit our testimony.

Mr. GORE. Well, do you understand why I still have the concern that I started with?

Dr. PEWITT. The statement is a statement for the record, and having talked to you in previous capacities, I expected to engage in dialog.

I have given this some thought, among several other things that we have been concerned about. It appears to me that we are asking how to build a highway, how to make that thing last. In fact, we know how to build a highway to last. The Romans knew how to build a highway to last and they still operate pretty well. One builds based on some expectation for use. Perhaps we have used the techniques of cost-benefit analysis, systems analysis, and overapplied them, and we certainly underbuilt the Interstate Highway

System. We underinvestigated. Those highways were not built to carry the loads. The fact of the matter is, if you design the system to carry 5 units of traffic per unit time, and you wind up with 10, you are not going to get the expected lifetime. We made some mistakes. We tend in this society to cut things very closely when we're making capital investments.

Mr. Gore. Let me short circuit what you're saying. Of course we know how to make roads that will last longer. But at the current state of knowledge there is relatively immutable relationship between duration and investment, and you can increase the durability of the highway *x* amount if you increase the investment *y* amount. We know, however, that that relationship is not really immutable, and that relationship can be changed with research.

We had really interesting testimony yesterday from people organizing private research efforts, like the fellow from IBM, and he said when you're designing a new computer system some people have the idea that you want to put all of your research into the microchip and all of the effort is focused on that; but he said a lot of times the real savings and the real improvements are going to come from research into that typewriter key hitting the paper and the ribbon. You have got to research improvements and identify opportunities to improve and make more productive all parts of the system.

OSTP is making that mistake, in all due respect. We are really focusing on the exotic, high-energy physics areas, but when it comes to the tens of billions of dollars that we're going to ask the public to hike out in regressive taxes to fund highway construction continuously over and over and over again, we don't put any effort into research that will improve that task. We just sort of short term and pave it over again. We're sort of "asphalt junkies" and we don't break that cycle and take the time and make the effort to improve that process, to break that relationship between investment and durability.

Do you want to respond briefly?

Dr. Pewitt. Well, a number of scientists have come by and talked to us about their clever ideas for how to address this infrastructure problem. It's not just highways and bridges. It's sewers and subways systems in our larger cities, too. And the problem is wishing something so does not make it so in the world of science. The question I always put to these people who have proposed these ideas to me is what is your specific program. We all recognize the problem. What is the approach that we should pursue? Until our office is presented with a plan with some efficacy to it by the agencies, and I'm sure the Department of Transportation is looking at ways to do this. We have very little basis in which to support an increase in a research program. We just simply have not seen it. We remain open, but right now it is——

Mr. Gore. In other words, the ball's in DOT's court?

Dr. Pewitt. The ball is in the advocate's court too. In fact, present something to us that has some technical efficacy.

Mr. Gore. You recognize the good sense of an effort to make our research programs more productive and try to cut down on this new wave of investment coming along, but the ball is in DOT's court to argue it with the Executive Office of the President and OSTP for an effective research program?

Dr. PEWITT. And we will support the Department of Transportation and other advocates in that arena if there is technical efficacy.

I would like to say that we haven't ignored this. As a matter of fact, I think I am the first senior member of OSTP in a long time who has actually gone out to the Transportation Research Center and spent some time out there reviewing their programs and the types of activities they have been involved in. We are perfectly prepared to support the Secretary in this area, given the fact that something comes forth.

Mr. GORE [presiding]. Thank you very much.

Mr. Skeen?

Mr. SKEEN. Dr. Pewitt, I would tell you that I am delighted to have you here this morning.

You know, this is similar to the situation that we have in the West, when one cow shows up and the guy's got a whole pickup load of feed he dumps it all on one cow. That's kind of what happened to you this morning.

We share your frustration along with everyone else in this country on infrastructure because we put a lot of money in this wonderful system. We've got the best system in the world, transportation-wise, and as you mentioned, it is not just the transportation system. It is all the other interrelated ones.

I want to congratulate you and Mrs. Dole for the kind of work that is going on over there between the OSTP and the Department of Transportation. She has been to our State. We have a grievous problem, a large State with a lot of important roads and arterials as our lifeblood, along with the city support that we have in sewers and those kinds of things that make a city habitable. We appreciate the interest you have in a State that has a very low population and has trouble coming up with these kinds of funds.

As one who is an engineer and practiced in that field some time ago, it has been amazing to me the transition that has been made in the technological standards of materials for one thing. It has been so rapid. Also, the cost of materials has changed drastically over the time. Asphalt—as the chairman pointed out, we're asphalt junkies. But we were up to the point on the part of the petroleum industry, that it became so expensive that we tried to find other materials or some way to save the use of asphaltic materials in road construction and other types of utilization.

I just think this is one of the problems we have that cannot be fingerprinted to one administration because it has covered a great many, over a span of years. Our concepts in technical changes and materials and the strength of materials, the characteristics of materials, has changed drastically as well. So rather than try to become abusive about what is going on with the OSTP and changing all the policy and correcting all the mistakes that have been made over the years, I just want to say to you that I think you're going in the right direction and that you're trying. I appreciate that very much.

I'm going to leave and go vote.

Mrs. SCHNEIDER. Mr. Chairman, I would like to have the opportunity to ask my questions, if you gentlemen would like to go and vote, because I will not be able to return after the vote. So if I may proceed——

Mr. GORE. That's fine. We will turn the gavel over to you.

Mrs. SCHNEIDER [presiding]. Thank you kindly.

Dr. Pewitt, I would like to identify myself with the remarks of the gentleman from New Mexico. I, too, am quite pleased with the direction and some of the activities that you have been promoting.

I do have a question, though, based on your testimony. If you could better define or articulate for me what role you see the Federal Government playing versus industry or the private sector in the whole area of R&D, what kind of sharing arrangement do you recommend?

Dr. PEWITT. You mean with regard to the transportation research?

Mrs. SCHNEIDER. Yes.

Dr. PEWITT. I don't have a menu of items. Take for example the highways, we have long since stopped building private highways and charging people to travel over them. This is clearly public and a responsibility of government. Now, that responsibility is clearly divided between the States and Federal Government. As a matter of efficiency there is, however, no point that every State should have a highway building research program since in large measure the same research questions would be addressed by every State, so there is clearly a Federal role. We are the big consumer of highway building. It is a legitimate function of this Government to invest in research on the building of bridges and the building of roads.

Now, there is clearly a dividing line when one gets into who is going to make the best commercial product, the best sorts of steels for bridges, et cetera. Those are lines that take a great deal of understanding. For our office to get into these areas would be as major an undertaking as our previous transportation activities have been. For instance, that was in aeronautics R&D and in the FAA's air traffic control program. Those are major undertakings and we simply have not done that. So we don't have the specifics. The general policies I think you understand.

Mrs. SCHNEIDER. Let me ask a more parochial question.

You had mentioned that we have the capability of building a bridge and not necessarily of repairing a bridge well. Do we have the capability and technical ability to detect structural instability of a bridge?

Dr. PEWITT. Nondestructive evaluation, of materials, everything from reactor vessels for nuclear powerplants, which are of immense concern, to flaws in the wings of airplanes, is a matter of very active research. Certainly it presents one of the most interesting scientific programs in nondestructive evaluation, which would be applicable to bridges presents one of the most interesting scientific problems, and is an area of very major emphasis.

The answer is that we never do know how to evaluate things well enough, but it is an area we have been concerned with in a number of fields. It would certainly be applicable to bridge construction.

Mrs. SCHNEIDER. I regret that I have to run, and literally run, to make this vote. So the committee will be adjourned for 10 minutes.

I would appreciate it if you could elaborate a little bit on being able to detect the quality or lack thereof of bridges, because we recognize many of them were built many years ago and we are noticing a number of them are collapsing. Seeing how I have to cross one throughout my district all the time, I have to say my prayers.

Dr. PEWITT. We will provide something for the record for you, if that's adequate.

Mrs. SCHNEIDER. Fine.

[The information follows:]

BRIDGE QUALITY R&D

The Federal Highway Administration has an active program of R&D on the detection, monitoring, and measurement of anomalies in bridge components. A variety of non-destructive methods are being developed which satisfy the conditions that govern routine bridge inspections - i.e. the equipment must be portable, self-contained, and simple to operate. These methods include acoustic crack detection and magnetic crack definition, magnetic field disturbance detection, photon tomography, radar, and nuclear magnetic resonance. Some of the latest equipment, by incorporating microprocessors, makes it possible to collect and process vast quantities of data with subsequent graphical reconstruction.

Ongoing research projects are examining the effects of residual stresses in welded steel highway bridges, and developing ultrasonic automatic flaw imaging systems for the accurate sizing and location of bridge anomalies.

[Whereupon, the subcommittees were in recess.]

Mr. GLICKMAN [presiding]. Now we have our last panel of witnesses, representatives of the Department of Transportation. We have the Honorable Charles Swinburn, Deputy Assistant Secretary for Policy and International Affairs, Howard Dugoff, Administrator, Research and Special Programs Administration, U.S. Department of Transportation, and Lester P. Lamm, Deputy Administrator of the Federal Highway Administration.

However you wish to testify is fine with me, since you're all from the same Department. So who is going to go first?

Mr. SWINBURN. I will, Mr. Chairman.

Mr. GLICKMAN. OK. And your entire statements will appear in the record, so if you wish to summarize, that would be fine with me.

STATEMENTS OF CHARLES SWINBURN, DEPUTY ASSISTANT SECRETARY FOR POLICY AND INTERNATIONAL AFFAIRS, DEPARTMENT OF TRANSPORTATION; HOWARD DUGOFF, ADMINISTRATOR, RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION; AND LESTER P. LAMM, DEPUTY ADMINISTRATOR, FEDERAL HIGHWAY ADMINISTRATION, ACCOMPANIED BY EDWIN WOOD, ASSOCIATE ADMINISTRATOR FOR RESEARCH, DEVELOPMENT, AND TECHNOLOGY

Mr. SWINBURN. Thank you, sir. We will summarize our statements for you and, hopefully, Mr. Dugoff and I will be quite brief so that Mr. Lamm, who is dealing with the specific subject matter that you're most interested in, will have some time.

I will first discuss the Department's overall R&D policy, structure and programs. Mr. Dugoff will talk about activities at the Transportaton Systems Center and our university research program. Mr. Lamm will then get into the R&D as it applies to our highway and bridge programs.

It is important to recognize that we start with transportation systems which are, for the most part, built and in place. We have an extensive network of highways, railways, waterways, pipelines and airports. Our current primary concerns are with effectively maintaining and improving those systems.

In the highway area, the need to shift our emphasis from new construction to reconstruction was clearly spelled out in the Surface Transportation Assistance Act of 1982 and has been mentioned by all of the witnesses and by yourself, Mr. Chairman, in the course of these hearings. Funds for repair in the Surface Transportation Assistance Act were significantly increased, and the act included specific requirements for using a certain amount of this money on highway and bridge repairs. As a consequence of this congressional direction, and the need to preserve existing transportation structures, future research emphasis will be principally on ways to make the existing system work better, more safely and economically, through both physical and operating improvements.

The nature of the Federal Government's involvement in research and development is a significant issue. In general, it is our belief that the Federal Government should not be so deeply and broadly involved in the details of making transportation decisions as it has been in the past. In most cases, State and local governments and the private sector are better situated to make these decisions.

In keeping with that belief, we are attempting to concentrate our R&D in areas, first, that have a recognized governmental mission, such as safety. Some of this type of R&D is present in all of our model administrations.

Second, where R&D is clearly in the national interest and the investment won't be made privately. This is the case with much of our highway R&D.

Third, where there is direct government operating responsibility, such as in air traffic control.

And fourth, where the national security and emergency preparedness are involved.

The nature of the Department's R&D efforts are quite varied, since transportation encompasses a wide range of activities with vastly different requirements and a variety of users. Also, the organization of the Department strongly influences the character of the transportation R&D programs.

For your reference, I have attached a DOT organization chart to my testimony. As you will see, DOT has a highly decentralized structure, comprised of nine operating administrations that report directly to the Secretary and have responsibility for their respective areas. Additionally, acting as staff advisers to the Secretary are four Assistant Secretaries, a General Counsel, and the Inspector General, whose functional responsibilities cut across modal programs.

The Department's overall R&D budget requests for fiscal year 1984 are estimated to exceed $500 million, an increase of $126 million over fiscal year 1983 appropriations. More than half of this will support the Federal Aviation Administration's efforts to improve the safety and productivity of the national airspace system, including upgrading the air traffic control system. The major expenditures for each administration are included in my statement for the record.

I hope this brief overview gives you an idea of how the highway R&D fits with other R&D activities of the Department. At the conclusion of our testimony, we will be happy to answer questions from the committee.

[The prepared statement of Mr. Swinburn follows:]

STATEMENT OF
DEPUTY ASSISTANT SECRETARY FOR POLICY AND INTERNATIONAL AFFAIRS
CHARLES SWINBURN
BEFORE THE SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT
AND
THE SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS
JUNE 16, 1983

Mr. Chairman and Members of the Subcommittee:

I appreciate the opportunity to appear before you to discuss the Department's research in transportation infrastructure. With me today are Howard Dugoff, the Administrator of the Research and Special Programs Administration, Les Lamm, the Deputy Federal Highway Administrator, and Ed Wood, FHWA's Associate Administrator for Research, Development and Technology. I will first discuss the Department's overall R&D policy and programs, and how highway R&D fits within the context of our research efforts. Mr. Dugoff will then discuss activities at the Transportation Systems Center and under the university research program, as well as some specific transportation infrastructure projects. Finally, Mr. Lamm will discuss the highway R&D program and some of the more important R&D policy concerns and directions for the future. We understand that you are particularly interested in R&D and its connection to highway and bridge repair and rehabilitation and, thus, Mr. Lamm's prepared testimony deals with those subjects in considerable detail.

It is important to recognize when discussing these subjects that we start with the Nation's transportation systems which are, for the most part, built and in place. We have an extensive network of highways, railways, waterways, pipelines and airports. Our current primary concerns are not with building, but with effectively maintaining and improving the system built in the past. With respect to the Interstate Highway System, the need to shift our emphasis from new construction to reconstruction was clearly spelled out in the Surface Transportation Assistance Act of 1982. Funds for repair were significantly increased and the Act included specific requirements for using a certain amount of this money on highway and bridge repairs. As a consequence of this Congressional direction, as well as the clear need to preserve existing transportation structures, future research emphasis will be principally on ways to make the existing system work better, more safely and economically, through both physical and operating improvements.

The nature of the Federal government's involvement in research and development is a significant issue. In keeping with the Administration's policy, the Federal government should not be so deeply and broadly involved in the details of making transportation decisions as it has been in the past. State and local governments and the private sector are better situated to make these decisions in all but a limited number of cases and programs that are of high national interest and priority. The Department is committed to the following major transportation policy principles:

1. Non-Federal interest transportation functions should be returned to state and local governments.

2. Reliance on the private sector and on market mechanisms should be increased, through the return of transportation functions to private operation, wherever possible.

3. Federal regulations should be reviewed and reformed in order to eliminate or modify requirements whose costs exceed their benefits, and

4. Federal capital investments in transportation facilities should meet sound cost-benefit standards.

The current Federal role in transportation research and development reflects these policies and, in the future, the Department's R&D will increasingly be concentrated in areas:

1. That have a recognized governmental mission, such as safety, or where government activity is directly required by statute or where government has a continuing regulatory role;

2. Where R&D is clearly in the national interest, but some peculiarity of the free market or industry structure prevents the investment from being made privately;

3. Where there is direct government operating responsibility, such as marine navigation and air traffic control; and

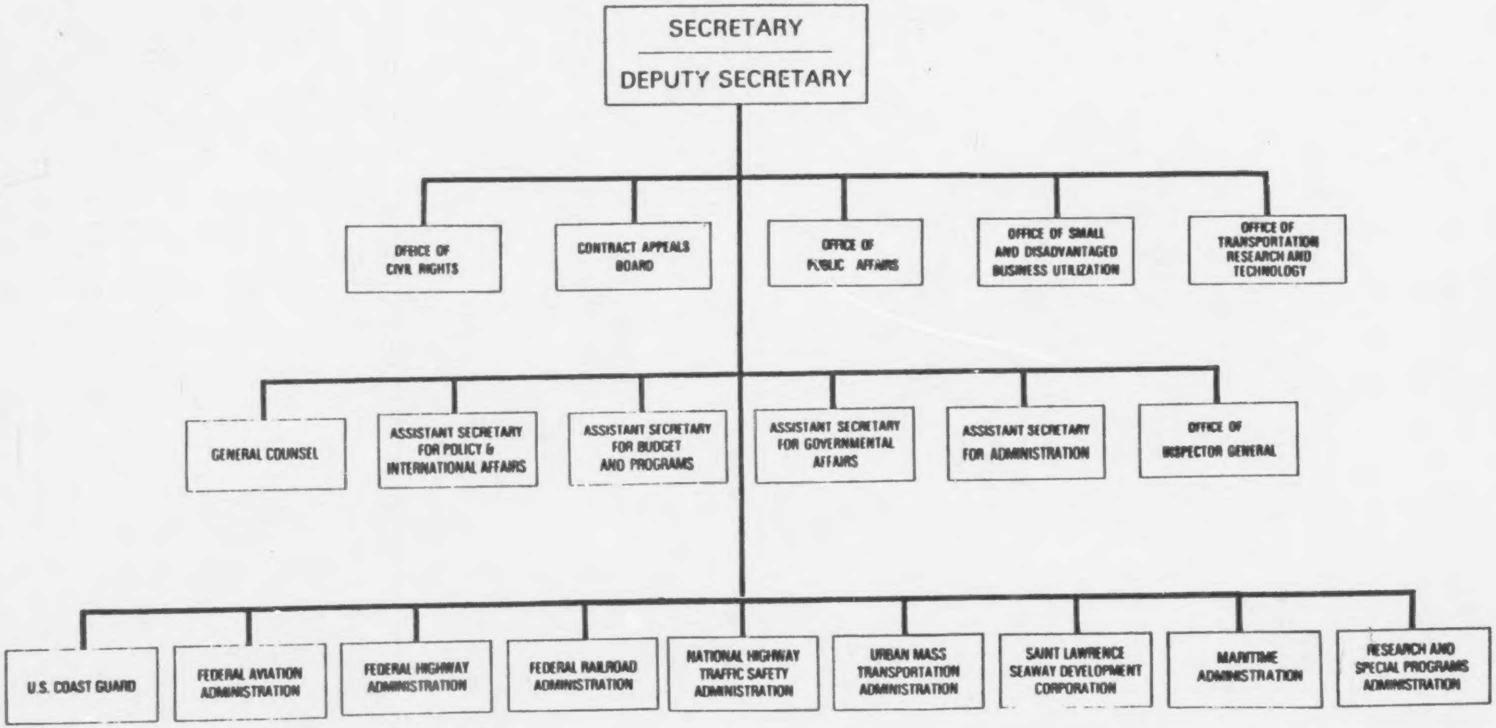
4. Where the national security and emergency preparedness are involved.

The nature of the Department's R&D efforts are quite varied, since transportation encompasses a wide range of activities with vastly different requirements and a variety of users. Also, the organization of the Department strongly influences the character of the R&D programs. For your reference I have attached a DOT Organization chart to my testimony. As you will see, DOT has a highly decentralized structure, comprised of nine operating administrations that report directly to the Secretary and have responsibility for their respective modal areas. Additionally, acting as staff advisors to the Secretary are four Assistant Secretaries, a General Counsel and the Inspector General, whose functional responsibilities (policy, budget, administration, governmental affairs, legal activities and audit and investigation) cut across modal programs. These staff positions do not, however, have direct authority. There also is a small immediate staff reporting to the Secretary with responsibility for such areas as civil rights.

The Department's overall R&D budget requests for Fiscal Year 1984 are estimated to exceed $500 million, an increase of $126 million over FY 1983 appropriations. More than half ($304 million) will support the Federal Aviation Administration's efforts to improve the safety and productivity of the national airspace system. One of the major components of this effort is the upgrading of the air traffic control system, so as to increase the capacity of the system to meet future traffic demands. Other major expenditures will include $22 million for the Coast Guard's efforts to improve search and rescue systems, aids to navigation, boating safety, port safety and icebreaking technology. The Federal Highway Administration will obligate $49 million (prior to enactment of the 1982 Act) to continue research in planning, designing, constructing and maintaining highways and in improving safety with special emphasis on the latter two areas. The National Highway Traffic Safety Administration will spend about $57 million, primarily for improving safety of motor vehicles and for demonstrations emphasizing safety belt usage and alcohol countermeasures. Another $46 million will be used by UMTA to assist in the development of improved mass transit system, equipment and procedures. The Federal Railroad Administration will obligate $17 million to continue safety research and the Maritime Administration will obligate $13 million to improve the productivity and competitive posture of the U.S. maritime industries. The Research and Special Programs Administration will obligate $5 million to support emergency preparedness and for hazardous material and pipeline safety regulatory programs and the Office of the Secretary will obligate $7 million for broad based policy research on domestic and international transportation issues.

I hope this brief overview gives you an idea how the highway R&D fits with other R&D activities of the Department. At the conclusion of our testimony, we will be happy to answer questions from the Committee.

U.S. DEPARTMENT OF TRANSPORTATION


SECRETARY
DEPUTY SECRETARY
OFFICE OF CIVIL RIGHTS
CONTRACT APPEALS BOARD
OFFICE OF PUBLIC AFFAIRS
OFFICE OF SMALL AND DISADVANTAGED BUSINESS UTILIZATION
OFFICE OF TRANSPORTATION RESEARCH AND TECHNOLOGY
GENERAL COUNSEL
ASSISTANT SECRETARY FOR POLICY & INTERNATIONAL AFFAIRS
ASSISTANT SECRETARY FOR BUDGET AND PROGRAMS
ASSISTANT SECRETARY FOR GOVERNMENTAL AFFAIRS
ASSISTANT SECRETARY FOR ADMINISTRATION
OFFICE OF INSPECTOR GENERAL
U.S. COAST GUARD
FEDERAL AVIATION ADMINISTRATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL RAILROAD ADMINISTRATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
URBAN MASS TRANSPORTATION ADMINISTRATION
SAINT LAWRENCE SEAWAY DEVELOPMENT CORPORATION
MARITIME ADMINISTRATION
RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION

Mr. GLICKMAN. OK. Mr. Dugoff?

Mr. DUGOFF. Thank you, Mr. Chairman.

It is a pleasure for me to appear here today to discuss very briefly some of the work performed by the Research and Special Programs Administration, and in particular to review some specific research activity related to the development and rehabilitation of transportation infrastructure.

The work I will discuss, as my colleague has pointed out, is carried out by two different organizational units—our Transportation Systems Center in Cambridge, Mass. and our Office of University Research here at DOT headquarters.

The Transportation Systems Center performs supporting R&D in a broad range of technical disciplines for each of the Department's operating administrations and the Office of the Secretary. The Center's work is not funded directly by congressional appropriation. Rather, individual projects are defined and funded through negotiated agreements with the departmental sponsors which seek technical assistance from the Center. Thus, the content and focus of the Center's program are shaped by the mission priorities and specific support needs of the other operating elements of the Department.

As has been discussed by Mr. Swinburn, the DOT element that bears responsibility for programs relating to the development and rehabilitation of roads and bridges is the Federal Highway Administration. Mr. Lamm will describe the well-developed administrative structure of the federally assisted highway R&D program and the strong Federal Highway Administration staff R&D capability. Given these resources, the Federal Highway Administration historically has not required technical assistance from the Transportation Systems Center in the traditional highway engineering disciplines, including those relating to the engineering aspects of road reconstruction and repair.

The relatively limited work which the center has performed in support of the Federal Highway Administration has focused primarily on economic analysis and assessment.

The Transportation Systems Center has played a more extensive role in support of other departmental sponsors' infrastructure programs, including light and heavy rail right-of-way rehabilitation, lock and dam reconstruction, and modernization of the national air traffic control system.

We have submitted substantially more detail on the Transportation Systems Center program for the record.

Our Office of University Research administers a comprehensive transportation research program on behalf and with the direct participation of all of the other operating elements of the Department. This program, unlike the work I described a moment ago at the Transportation Systems Center, is funded by a directly earmarked appropriation.

This University Research Program is specifically designed to elicit the independent ideas of the academic community as to the most promising research opportunities within the Department's priority problem agenda and the best conceptual and methodological approaches for attacking them. To this end, the program employs a procurement mechanism very different from the usual Departmental practice of soliciting competitive bids on the basis of extremely prescriptive and detailed problems and work statements. The annual solicitation of proposals for university research consists rather of a set of broad, topical research needs statements. University researchers are invited to identify a related problem or issue and propose a strategy to address it.

The research needs statements for the annual program soliciation are prepared by panels of experts drawn from technical staffs throughout the Department. A similar collegial process is employed to evaluate the proposals that are submitted.

During recent years, this process has reflected a substantial appreciation of the timeliness and importance of infrastructure research.

Although the 1983 project selection process is not yet completed, it is already apparent that several new projects in infrastructure research will be initiated, following on the heels of projects funded during the past several years on such related topics as concrete and other construction materials improvements; nondestructive testing methods for highways, bridges, and other structures—the subject of a question we heard a moment ago from Congresswoman Schneider—pavement deterioration caused by tire/pavement interactions, heavy traffic, and environmental factors; and forecasting of the effect of transportation infrastructure improvements on housing values and other factors affecting the local tax base.

A number of these projects have already produced results of sufficient promise for application that follow-on work has been initiated by the Federal Highway Administration. Incidentally, Mr. Chairman, this situation is quite typical of the modus operandi of the university research program. As the new ideas of independent researchers are brought to fruition, the cognizant modal administrations of the Department—in this case, the Federal Highway Administration—assume responsibility for their continued development.

A bibliography of recent university research program publications relating to transportation infrastructure will be submitted for the record.

In conclusion, Mr. Chairman, I would like to reiterate my view that the enhancement and promotion of transportation infrastructure research is just such a matter of high national interest, as my colleague, Mr. Swinburn, has identified as the proper focus of Federal Government attention.

Specifically, I think we need to provide a central focus for the research, assure a proper balance between short- and long-term emphasis, and foster a continuing flow of ideas from all of the experts in the field. It seems to me that the comprehensive and balanced program directed by the Federal Highway Administration, which Mr. Lamm will discuss with you in a moment, pursued within the policy framework outlined by Mr. Swinburn, and complemented by the supporting activities I have described, constitute a sensible and effective response to the needs.

I will now turn the floor over to Mr. Lamm.

[The prepared statement of Mr. Dugoff follows:]

STATEMENT OF
HOWARD DUGOFF
ADMINISTRATOR
RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION
BEFORE THE SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT
AND THE SUBCOMMITTEE ON TRANSPORTATION, AVIATION, AND MATERIALS
JUNE 16, 1983

Mr. Chairman and Members of the Subcommittee:

I am pleased to appear here today to outline the role played by the Research and Special Programs Administration (RSPA) in the research and development program of the Department of Transportation, and to review briefly some specific RSPA research projects relating to the development and rehabilitation of transportation infrastructure.

Mr. Swinburn has described the organization of the Department and explained how the operating administrations bear line responsibility for the implementation of Departmental programs. The distinguishing characteristic of RSPA is that our programs are multimodal, as contrasted with the mode-specific programs of our larger sister administrations. We bear primary responsibility for assuring safety in the transportation of hazardous materials in all modes, an important regulatory function that brings with it a substantial requirement for supporting R&D.

But our principal research activities, including those most pertinent to transportation infrastructure, are performed in response to requirements generated elsewhere in the Department. It is these general support activities, carried out by our Transportation Systems Center and our Office of University Research, that I will be discussing with you today.

Transportation Systems Center

The Transportation Systems Center (TSC) performs multi-disciplinary research for each of the Department's operating administrations and the Office of the Secretary. It provides expert technical support in such diverse areas as systems engineering and evaluation, economic impact analysis, technology transfer, and information and data management. TSC's work is not funded directly by Congressional appropriation. Rather, individual projects are defined and funded through negotiated agreements with the Departmental "sponsors" which seek technical assistance from the Center. Thus the content and focus of the Center's program are shaped by the mission priorities and specific support needs of the other operating elements of the Department.

As has been discussed by Mr. Lamm, the DOT element that bears responsibility for programs relating to the development and rehabilitation of roads and bridges is the Federal Highway Administration (FHWA). Mr. Lamm has described the well developed administrative structure of the Federally assisted highway R&D program and the strong FHWA staff R&D capability. Given these proven resources, the FHWA historically has not required technical assistance from TSC in the traditional highway engineering disciplines, including those relating to the engineering aspects of road reconstruction and repair. The work which TSC has performed in support of FHWA has focused primarily on economic assessment. This has included analysis of Federal investment and cost allocation strategies, with emphasis on social as well as economic impacts. The potential applications of this work in infrastructure redevelopment planning are quite substantial.

TSC has also performed related work on transportation infrastructure for other Departmental sponsors. Through projects funded by the Federal Aviation Administration, the Federal Railroad Administration, the Urban Mass Transportation Administration, and the U.S. Coast Guard, TSC has supported infrastructure programs ranging from light and heavy rail right-of-way rehabilitation, to lock and dam reconstruction, to modernization of the national air traffic control system.

A bibliography of recent TSC publications relating to transportation infrastructure is presented in Appendix I to this statement.

University Research

The Program of University Research focuses the talents and creative energies of the academic research community on long term transportation problems of priority concern to the Department. The program is administered by RSPA on behalf, and with the direct participation, of all of the other operating elements of the Department, funded by a directly earmarked appropriation .

The University Research Program is specifically designed to elicit the independent ideas of the academic community as to the most promising research opportunities within the Department's priority problem agenda and the best conceptual and methodological approaches for attacking them. To this end, it employs a procurement mechanism very different from the usual Departmental practice of soliciting competitive bids on the basis of extremely prescriptive and detailed problem and work statements. The Annual Solicitation of Proposals for University Research consists rather of a set of broad, topical research-needs statements. University researchers are invited to identify a related problem or issue and propose a strategy to address it.

The research needs statements for the Annual Program Solicitation are prepared by panels of experts drawn from technical staffs throughout DOT. A similar collegial process is employed to evaluate proposals that are submitted. Recommendations for project funding are made by a selection board comprised of the Department's senior R&D managers, under my chairmanship, and approved by the Deputy Secretary.

During recent years, this process has reflected a substantial appreciation of the timeliness and importance of infrastructure research; the last several Program Solicitations have included directly related needs statements. The 1983 Solicitation, for example, includes two such statements, under the titles, "Transportation Technology," and "Transportation Investment and Financing." Suggested sub-topics include (1) rehabilitation and maintenance, (2) control strategies, (3) technology assessment, (4) fiber composites for bridge construction, (5) investment strategies, (6) efficiency and productivity, and (7) contracting for highway projects.

We have received a number of interesting infrastructure research proposals in response to the 1983 University Research Program Solicitation. Although the selection process is not yet completed, it is apparent that several promising projects will be initiated, following on the heels of projects funded during the past several years on such related topics as: concrete and other construction materials improvements; non-destructive testing methods for highways, bridges, and other structures; pavement deterioration caused by tire/pavement interactions, heavy traffic, and environmental factors; and forecasting of the effect of transportation infrastructure improvements on housing values and other factors affecting the local tax base. A number of these projects have already produced results of sufficient promise for application that follow-on work has been initiated by the FHWA. (It is quite common for new research ideas initially developed under the University Research Program to be "handed off" to the cognizant modal administration for application and dissemination in the field.)

A bibliography of recent University Research Program publications relating to transportation infrastructure is presented in Appendix II to this statement.

Concluding Remarks

In this short statement, I have tried to briefly describe the context and content of the transportation infrastructure research performed by RSPA to complement the principal Departmental program under the auspices of FHWA. In closing, I want to second the opinion of my colleague, Mr. Swinburn, that the Federal government should disengage itself from the details of decisionmaking associated with transportation system operations, instead we should concentrate on matters of high national interest. One such matter is the enhancement and promotion of transportation infrastructure research.

Specifically, we need to provide a central focus for the research, assure a proper balance between short and long-term emphasis, and foster a continuing flow of ideas from all of the experts in the field. Our challenge is to oversee a national program utilizing the resources available at all levels of government and in the private sector so that new technology can be developed and applied as quickly and efficiently as possible.

I believe that the comprehensive and balanced program directed by FHWA, pursued within the policy framework outlined by Mr. Swinburn, and supported and complemented by the RSPA efforts I have described, constitute a sensible and effective response to the needs.

My colleagues and I will be pleased to respond to your questions.

APPENDIX I

Transportation Systems Center Reports* On Transportation Infrastructure Topics, 1979-83

Studies for FAA

DOT-TSC-FAA-81-24
STUDY OF THE DE-ICING PROPERTIES OF THE ASDE-3 ROTODOME
Merrill K. Goulding & Associates, Glendale, CA
Merrill K. Goulding
DOT-FAA-RD-81-112
TS-15950
Final Report April 1982 132p.

DOT-TSC-FAA-82-1
EVALUATION AND APPLICATION OF ENHANCEMENTS TO THE PERFORMANCE OF THE ASDE-3 RADAR IN HEAVY RAIN
Transportation Systems Center
G.J. Bishop
DOT-FAA-RD-81-94
Final Report September 1981

DOT-TSC-FAA-81-20
AN ANALYSIS OF SELECTED ENHANCEMENTS TO THE EN ROUTE CENTRAL COMPUTING COMPLEX
Transportation Systems Center
William Broadley, Harvey Freeman, James Oiesen,
Ronald Rutledge, and Kenneth Thurber
FAA-EM-81-18
Final Report September 1981 104p.

Studies for FHWA

DOT-TSC-FHWA-79-1
EFFECTIVENESS OF SPEED CONTROL SIGNS IN RURAL SCHOOL ZONES AND SMALL COMMUNITIES
Transportation Systems Center
Joseph S. Koziol, Jr., Ann R. Fulchino, Peter H. Mengert, and
Gerald Stewart
PB-301 110
FHWA/RD-79/20
Final Report July 1979 155p.

*Includes selected reports on transportation infrastructure topics authored by Transportation Systems Center (TSC) analysts or by organizations under contract to TSC. Transportation infrastructure is used here to mean underlying physical, capital facilities such as roads, railroads and communication systems.

Studies for FRA

DOT-TSC-FRA-79-1
RAIL-HIGHWAY CROSSING HAZARD PREDICTION RESEARCH RESULTS
Transportation Systems Center
Peter Mengert
PB80-170749
FRA-RRS-80-02
Final Report Dec. 1979 254p.

DOT-TSC-FRA-80-4,1
STATISTICAL REPRESENTATIONS OF TRACK GEOMETRY
Volume 1: Main Text
Transportation Systems Center
John C. Corbin
FRA/ORD-80/1.1
DOT-TSC-1211-1
Final Report January 1980 208p.

DOT-TSC-FRA-82-5
BALLAST AND SUBGRADE REQUIREMENTS STUDY: SUMMARY AND ASSESSMENT REPORT
Goldberg-Zoino & Associates, Inc., Newton Upper Falls, Massachusetts
Simon, R. M., DiPilato, M. A.
FRA/ORD-83/04.3
DOT/TSC-1527
Final Report June 1983 84p.

DOT-TSC-FRA-83-1
PARAMETRIC STUDIES ON LATERAL STABILITY OF WELDED RAIL TRACK
Transportation Systems Center
G. Samavedam, A. Kish, D. Jeong
DOT/FRA/ORD-83/07
Interim Report May 1983 60p.

Studies for NHTSA

DOT-TSC-NHTSA-79-45
NOISE ABATEMENT TECHNIQUES FOR CONSTRUCTION EQUIPMENT
Society of Automotive Engineers, Inc.
William J. Toth
PB-300 948
DOT-HS-803 293
DOT-TSC-915
Final Report August 1979 187p.

Studies for UMTA

DOT-TSC-UMTA-79
CONSTRUCTION OF URBAN RAIL TRANSIT
SYSTEMS: THE CHALLENGE OF MORE COST
EFFECTIVE CONSTRUCTION
Pacific Consultants
Roger W. Dewey
Conference Proceedings Held at Williamsburg, Virginia
on December 7-8, 1978
PB80-130479
UMTA-MA-06-0100-79-7
DOT-TSC-1526
September 1979 106p.

DOT-TSC-UMTA-79-4
ECONOMIC FACTORS IN TUNNEL CONSTRUCTION
Underground Technology Development Corp.
E.L. Foster, R. McDonald, W. Wightman, and I. Taporoff
Prepared in cooperation with Singstad, Kehart, November, and
Hurka, New York
PB-294 726
UMTA-MA-06-0025-79-10
DOT-TSC-1106
Final Report February 1979 306p.

DOT-TSC-UMTA-79-7
STREETS FOR PEDESTRIANS AND TRANSIT:
AN EVALUATION OF THREE TRANSIT MALLS
IN THE UNITED STATES
Crain and Associates
Richard Edminster and David Koffman
PB-295 728
UMTA-MA-06-0049-79-1
DOT-TSC-1081
Final Report February 1979 255p.

DOT-TSC-UMTA-79-10
NATIONAL ASSESSMENT OF URBAN RAIL NOISE
Transportation Systems Center
Gregory Chisholm, Herbert Bogen, Michael Dinning, and
Michael Primeggia
PB-295 752
UMTA-MA-06-0099-79-2
Final Report March 1979 303p.

DOT-TSC-UMTA-79-17
PRELIMINARY SPECIFICATIONS FOR
STANDARD CONCRETE TIES AND FASTENINGS
FOR TRANSIT TRACK
Portland Cement Association, Skokie, IL
Construction Technology Labs.
Armir N. Hanna
PB-297-850
UMTA-MA-06-0100-79-3
DOT-TSC-1442
Final Report March 1979 50p.

DOT-TSC-UMTA-79-18
MEASUREMENT PROGRAM FOR EVALUATION OF CONCRETE TIES AND FASTENINGS IN TRANSIT TRACK
Portland Cement Association, Skokie, IL
Construction Technology Labs.
Amir N. Hanna
PB-297-570
UMTA-MA-06-0100-79-2
DOT-TSC-1442
Final Report March 1979 42p.

DOT-TSC-UMTA-79-24
LABORATORY EVALUATION OF CONCRETE TIES AND FASTENINGS FOR TRANSIT USE
Portland Cement Association, Skokie, IL.
Construction Technology Labs.
Amir N. Hanna
PB-297 533
UMTA-MA-06-0100-79-8
DOT-TSC-1442
Final Report March 1979 79p.

DOT-TSC-UMTA-79-29
MATERIALS HANDLING FOR URBAN TUNNELING IN ROCK
Holmes and Narver, Inc., Orange, CA
J.M. Duncan, L.A. Giamboni, H.V. Schneider, and P.E. Sperry
PB-299 117
UMTA-MA-06-0100-79-9
DOT-TSC-1281
Final Report May 1979 349p.

DOT-TSC-UMTA-79-35
EXTRUDED TUNNEL LINING SYSTEM, PHASE I--CONCEPTUAL DESIGN AND FEASIBILITY TESTING
Transportation Systems Center
Brian J. Doherty, Douglas, W. Ounanian, Kenneth R. Maser
PB80-118011
UMTA-MA-06-0100-79-11
DOT-TSC-1516
Final Report September 1979 210p.

DOT-TSC-UMTA-80-27,1
IMPROVED DESIGN OF TUNNEL SUPPORTS
Volume 1: Simplified Analysis for
Ground-Structure Interaction in Tunneling
Massachusetts Inst. of Tech., Cambridge
Dept. of Civil Engineering
Charles W. Schwartz and Herbert H. Einstein
PB80-225147
UMTA-MA-06-0100-80-4
DOT-TSC-1489
Final Report June 1980 438p.

DOT-TSC-UMTA-79-49
IMPROVED DESIGN OF TUNNEL SUPPORTS:
EXECUTIVE SUMMARY
Transportation Systems Center
Herbert H. Einstein, Amr S. Azzouz, Charles W. Schwartz,
and Walter Steiner
Massachusetts Inst. of Techn., Cambridge
Dept. of Civil Engineering
PB80-134547
UMTA-MA-06-0100-79-15
DOT-TSC-1489
Final Report December 1979 55p.

DOT-TSC-UMTA-80-27,1
IMPROVED DESIGN OF TUNNEL SUPPORTS.
Volume 1: Simplified Analysis for
Ground-Structure Interaction in
Tunneling
Massachusetts Inst. of Tech., Cambridge,
Dept. of Civil Engineering
Charles W. Schwartz, and Herbert H. Einstein
PB80-225147
UMTA-MA-06-0100-80-4
DOT-TSC-1489
Final Report June 1980 438p.

DOT-TSC-UMTA-80-27,2
IMPROVED DESIGN OF TUNNEL SUPPORTS.
Volume 2: Aspects of Yielding in
Ground-Structure Interaction
Massachusetts Inst. of Tech., Cambridge
Dept. of Civil Engineering
Charles W. Schwartz, Amr. S. Azzouz, and Herbert H. Einstein
PB80-225147
UMTA-MA-06-0100-80-5
DOT-TSC-1489
Final Report June 1980 78p.

DOT-TSC-UMTA-80-27,3
IMPROVED DESIGN OF TUNNEL SUPPORTS.
Volume 3: Finite Element Analysis of
the Peachtree Center Station in Atlanta
Massachusetts Inst. of Tech., Cambridge,
Dept. of Civil Engineering
Amr S. Azzouz, Charles W. Schwartz, and Herbert H. Einstein
PB80-225170
Set: PB80-225147
UMTA-MA-06-0100-80-6
DOT-TSC-1489
Final Report June 1980 111p.

DOT-TSC-UMTA-80-31
SEGMENTED CONCRETE TUNNEL LINER AND SEALANT SYSTEMS
Water and Power Resources Service , Denver, CO
C.E. Selander, C.A. Nelson, F.J. Jackmauh,
J.F. Steighner, B.V. Jones, H. Johns, H.K. Uyeda
UMTA-MA-06-0100-80-9
(RA) 76-22
Final Report July 1980 354p.

DOT-TSC-UMTA-81-22
TECHNICAL AND ECONOMIC FEASIBILITY STUDY OF
AT-GRADE CONCRETE SLAB TRACK FOR URBAN
RAIL TRANSIT SYSTEMS
Construction Technology Laboratories, Skokie, Illinois
Amir N. Hanna
UMTA-MA-06-0100-81-4
DOT-TSC-1765
Final Report August 1981 224p.

DOT-TSC-UMTA-81-60
ASSESSMENT OF LOW-COST ELEVATORS FOR NEAR
TERM APPLICATION IN TRANSIT STATIONS
Dynatrend Incorporated, Woburn, MA
Kevin M. Shea, M. Ray Whitley, and
Braja S. Mahapatra, Southeastern Pa., Trans. Auth.,
UMTA-MA-06-0125-82-1
DTRS-57-80-C-0081
Final Report July 1982 68p.

DOT-TSC-UMTA-81-69
LIMITING FORCES ON TRANSIT TRUCKS IN STEADY-STATE CURVING
Transportation Systems Center
R. Grief, and H. Weinstock
UMTA-MA-06-0025-82-1
Interim Report May 1982 58p.

DOT-TSC-UMTA-81-73
HANDBOOK OF URBAN RAIL NOISE AND VIBRATION CONTROL: EXECUTIVE DIGEST
Wilson, Ihrig & Associates, Oakland, CA
Hugh J. Saurenman, James T. Nelson, George P. Wilson
UMTA-MA-06-0099-82-2
DOT-TSC-1613
Final Report July 1982 60p.

DOT-TSC-UMTA-81-75
HARMONIC CHARACTERISTICS OF RECTIFIER SUBSTATIONS AND THEIR IMPACT ON AUDIO FREQUENCY TRACK CIRCUITS
OAO Corporation, Greenbelt, Maryland
Vilas D. Nene, Ph.D.
UMTA-MA-06-0025-81-6
DTRS-57-81-C-00033
Final Report May 1982 60p.

DOT-TSC-UMTA-82-15
EVALUATION OF THE TRANSIT RELIABILITY INFORMATION PROGRAM
Rail Systems Center, Pittsburgh, PA
Richard A. Uher
UMTA-MA-06-0126-82-1
DTR-57-82-P-80228
Final Report July 1982 176p.

DOT-TSC-UMTA-82-54,1
DEVELOPMENT OF A DESIGN TECHNOLOGY FOR GROUND S SUPPORT FOR TUNNELS IN SOIL. VOLUME I: TIME-DEPENDENT RESPONSE DUE TO CONSOLIDATION IN CLAYS.
Stanford University, Stanford, California
P.R. Johnston, and G.W. Clough
UMTA-MA-06-0100-82-1
DOT-TSC-1726
Final Report February 1983 233p.

DOT-TSC-UMTA-82-55
RAPID TRANSIT CAR MAINTENANCE RESEARCH NEEDS
The Decision Group, Inc., McLean, VA
UMTA-MA-06-0025-82-6
Final Report December 1982 184p.

DOT-TSC-UMTA-82-57
CONTROL OF WHEEL/RAIL NOISE AND VIBRATION
Bolt Beranek and Newman Inc., Cambridge, MA
P.J. Remington, N.R. Dixon, L.G. Kurzweil,
C.W. Menge, J.D. Stahr, L.E. Wittig
UMTA-MA-06-0099-82-5
DOT-TSC-1768
Final Report April 1983 348p.

Studies for RSPA

DOT-TSC-RSPA-83-2
NAVSTAR GPS SIMULATION AND ANALYSIS PROGRAM
Transportation Systems Center
R.M. Kalafus, J.. Kraemer, N. Knable, J. Vilcans
DOT-TSC-RSPA-83-2
Final Report May 1983 196p.

APPENDIX II

RESEARCH PROJECTS SPONSORED BY THE PROGRAM OF UNIVERSITY RESEARCH RELATING TO TRANSPORTATION INFRASTRUCTURE

ARIZONA STATE UNIVERSITY, #DOT-OS-50107, Guideway Vehicle Cost Reduction, David L. Klinger, 1975.

CALIFORNIA, UNIVERSITY OF, LOS ANGELES, #DOT-OS-40080, Dynamic Interactions and Optional Design of PRT Vehicles and Elevated Guideways, Richard B. Nelson, 1974.

CALIFORNIA STATE UNIVERSITY AT SACRAMENTO, #DOT-OS-40016, Analytical Techniques for Safety and Performance of Subsurface Transportation Structures, Lester H. Gabriel, 1974.

COLORADO SCHOOL OF MINES, #30123, Study of a Pneumatic-Hydraulic Material Transport System for Rapid Excavation of Machine-Bored Tunnels. 1973.

COLORADO SCHOOL OF MINES, #DOT-OS-40033, Feasibility of Improving the Efficiency of Mechanical Disk Rock Cuts, 1974.

COLORADO SCHOOL OF MINES, #DOT-OS-40102, Hyrdaulic Jet Assisted Tunnel Boring, 1974.

DUKE UNIVERSITY, #DOT-OS-60130, Dynamic Experiments of Alternative Guideway-Vehicle Systems, James F. Wilson, 1976.

GEORGIA INSTITUTE OF TECHNOLOGY, #DOT-OS-50226, Low Cost Bicycle Path Pavements, James S. Lai, 1975.

IOWA STATE UNIVERSITY, #DOT-RC-92012, Geophysical Grouting Control Systems, Irwin P. Levin, 1979.

ILLINOIS UNIVERSITY, Chicago Circle, #DOT-OS-30092, An Integrated Engineering-Planned Approach to the Preservation, Improvement and Replacement of Elevated Transportation Structures, Marshall Silver, 1973.

ILLINOIS UNIVERSITY, URBANA, #DOT-OS-70024, Tunneling Technology, 1977.

KENTUCKY, UNIVERSITY OF, #DTRS5681-C-0016, Tire/Roadway Interaction, Andrew F. Seybert, 1980.

LEHIGH UNIVERSITY, #DOT-RC-82007, Fracture Analysis of Pipelines, Fazil Erdogan, 1982.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, #DOT-OS-60136, Improved Design Procedure for Tunnel Supports, Herbert H. Einstein, 1976.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, #DTRS5680-C-00018, Suspension Techniques to Improve High Speed Ground Vehicles Performance, J. K. Hedrick, 1980.

MINNESOTA, UNIVERSITY OF, #DOT-OS-40087, Hydraulic Tunneling, Charles R. Nelson, 1974.

NEBRASKA, UNIVERSITY OF, #DOT-RC-92021, Cost Effectiveness of Retrofitting Concrete Median Barriers, Edward R. Post, 1979.

NEW YORK, POLYTECHNIC INSTITUTE OF, #DOT-OS-60139, Seminar on Polymeric Materials and Their Use in Transportation, ELi M. Pearce, 1976.

NEW YORK STATE UNIVERSITY AT BUFFALO, #DOT-OS-70058, A Theory for Track Maintenance Life Prediction, Ernest T. Selig, 1977.

NORTH CAROLINA STATE UNIVERSITY, #DTRS5681-C-00002, Tire/Pavement Interactions, Allen C. Eberhardt, 1981.

NOTRE DAME UNIVERSITY, #DTRS5681-C-00024, Soil Reinforcement - Soft Ground Tunneling, Sangchul Bang, 1981.

OAKLAND UNIVERSITY, #DTRS5681-C-0025, Testing Highway Structures, Y. Y. Hung, 1981.

OKLAHOMA UNIVERSITY, #DOT-OS-30110, Analysis and Management of a Pipeline Safety Information System, Michael D. Devine, 1973.

PENNSYLVANIA, UNIVERSITY OF, #DOT-OS-40093, Improved Wheel and Rail Performance Control of Contact Stress, Burton Paul, 1974.

PENNSYLVANIA, UNIVERSITY OF, #DOT-OS-60143, International Symposium on Freight Pipeline, Iraj Zandi, 1976.

PENNSYLVANIA, UNIVERSITY OF, #DOT-OS-60144, Fundamental Studies of Phenomena Related to Wheel-Rail Contact Stresses, Burton Paul, 1976.

PENNSYLVANIA STATE UNIVERSITY, #DOT-OS-40009, Advanced Technology Materials Applied to Guideways, Highways and Airport Runways, Della M. Roy, 1974.

PENNSYLVANIA STATE UNIVERSITY, #DOT-OS-60145, Investigation of the Transient Aspects of Hydroplaning, J. J. Henry, 1976.

PENNSYLVANIA STATE UNIVERSITY, #RC-82030, Fingerprinting vs. Field Performance of Paving Grade Asphalts, David Anderson, 1978.

PRINCETON UNIVERSITY, #DOT-RC-92033, Improvement in Rail Vehicle Dynamic Performance, Larry M. Sweet, 1979.

PURDUE UNIVERSITY, #OS-60088, Establish, Operate a Transportation Tunneling Technology Information Center, 1976.

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STANFORD UNIVERSITY, #DOT-OS-50123, Design Metholodogy for Soft Ground Grouted Tunnels, G. Wayne Clough, 1975.

STANFORD UNIVERSITY, #DOT-OS-60150, Development of Research in the Construction of Transportation Facilities: A Study of Needs, Objectives, Resources, and Mechanisms for Implementation, Boyd C. Paulson, Jr., 1976.

STANFORD UNIVERSITY, #DTRS5681-C-00027, Japanese Urban Excavation Technologies, Boyd C. Paulson, Jr., 1981.

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TEXAS, UNIVERSITY OF, AT AUSTIN, #DOT-OS-50126, Ride Quality Studies on Ground Based Transportation Systems, Anthony J. Healy, 1975.

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VIRGINIA POLYTECHNIC INSTITUTE, #DOT-RC-80013, Interaction/Load Transfer-Track Guideway, Systems, C. S. Desai, 1978.

WORCESTER POLYTECHNIC INSTITUTE, #DTRS5680-C-00035, Shear Strength Characteristics of Soils Subjected to Frost Action, Joseph D. Sage, 1980.

WYOMING, UNIVERSITY OF, #DOT-OS-40017, Thermodynamics of Bridges, Roadways, and Airport Runways, 1974.

Mr. GLICKMAN. Mr. Lamm.

Mr. LAMM. Thank you, Mr. Chairman. I, too, have a longer statement which I would appreciate being incorporated in the record. I will then summarize it for the committee this morning.

Mr. GLICKMAN. It will be included.

Mr. LAMM. I would like to talk a little bit about our management of the research and development activities in the highway field. With me, on my right, is Mr. Edwin Wood, who is our Associate Administrator for Research, Development and Technology, who will assist in answering questions the committee may have later.

Before I get into the research area, I might like to spend a minute mentioning to the committee what has happened in the 5 months-plus since the President signed the Surface Transportation Assistance Act of 1982, which provided subsequently sizable additional revenue to the States for highway and bridge improvements.

Since January 6, 1983, when the bill was signed, the States have collectively made great strides in using the additional funds which have been made available. At present, as of yesterday, the total amount of highway funds obligated by the States during fiscal year 1983 exceeded $7.8 billion. In nearly every other year, that has been a very fine and effective 12-month set of activities. The program level in 1983 is roughly 70 percent higher than it was at the same time in calendar year 1982. As a result, roughly 60,000 additional highway-related jobs are active now as compared to the program activity we had in 1982.

In addition, the many complex requirements of the bill are being implemented by the Federal Highway Administration and the Department. We have estimated that of the more than 100 different requirements contained in the legislation, nearly 50 have had complete implementation to this point and we are well underway on most others.

Turning now to research, the Federal Highway Administration has really been involved in highway research and development for 90 years. It was our first mission. I would like to be able to report to you that we have learned all that we need to know about highways in that time. Unfortunately, this is not the case.

Highway construction and maintenance activities have evolved greatly and changed massively over the years, and they are still changing today. This is clearly illustrated by problems which we now have with the composition of asphalt, a material which we customarily took for granted. We know now that we must find better ways to control the quality and consistency of asphalt mixes, and we must also develop substitute materials which could be used if asphalts were no longer produced in the future. This is only one area among many where the research challenge continues today.

In fiscal year 1983, the federally assisted highway research programs will obligate nearly $60 million. These funds are controlled through four major programs, which are the highway planning and research program, the national cooperative highway research program, the Federal Highway Administration's own administrative contract program, and our staff research activities. You have heard these items mentioned from earlier witnesses before the committee, and I would like to briefly summarize FHWA's involvement with them.

The highway planning and research program is the cooperative Federal-State venture in which 1½ percent of the total highway funds available to every State must be used to finance highway planning and highway research activities. The share allocated to research is determined by each State. It currently ranges from 5 percent to 55 percent, with an average nationally of about 20 percent, or $31 million out of roughly $151 million available to the States for research activities. The remainder is used for planning efforts, such as highway data collection and prediction of future system needs that would be available at the States.

States initiate R&D studies either with their own staff or by contract with public or private research organizations. Universities and colleges do a substantial portion of the State highway planning and research activity. We provide technical guidance and coordination. We review and approve the overall program with each individual State.

The national cooperative highway research program is a three-way contract between the American Association of State Highway and Transportation Officials, the Federal Highway Administration, and the Transportation Research Board. Research activities are selected by a special committee of AASHTO and administered by the Transportation Research Board with approval by State highway officials. Under this program, a portion of the HP&R funds are pooled by the States for research which responds to the collective needs of all States. The Federal Highway Administration reviews the contractor selection, program content, and completed work. Program composition is the prerogative of the States, and in fiscal 1983 roughly $6.8 million is available for this activity.

The Federal Highway Administration also conducts a major portion of its research and development work by Federal administrative contract. Funding comes from the Highway Trust Fund, out of our own administrative expenses, and it is reviewed, authorized, and appropriated annually by the Congress. These funds are separate and apart from the HP&R activity. They amount to roughly $21.5 million this year.

Contract research is performed by private firms, universities, nonprofit organizations, individual consultants, other Federal agencies, and State highway agencies.

The final activity, our staff research and development, is conducted, as you would expect, by our own employees. Staff research activities have recently been enhanced by the completion of a new research facility at our Turner-Fairbank Highway Research Center in McLean, Va. The new structure provides 80,000 square feet of laboratory, office, and support service space. We would be pleased to arrange a tour of these facilities if the committee members or staff would desire.

Roughly 20 percent of the total research and development employee time is spent conducting staff research. The remaining time is used to plan, administer, and monitor activities supported by Federal funds in the other three areas which I mentioned.

For fiscal 1982, the total Federal Highway Administration contract funds were $18.5 million, or two-tenths of 1 percent of the total highway funds authorized. With the addition of the staff research and the funds allocated to R&D by the States under the HP&R program, the total obligated last year for research was $40.3 million, or nearly one-half of 1 percent of the total Federal highway funds.

With the increased funds available from the Surface Transportation Assistance Act of 1982, the State allocations for research have increased from $19 million to $31 million. In addition, some States expect to supplement this program by an additional $12 million of their own funds.

The Federal Highway Administration is responsible, as I mentioned, for coordinating the activities within these four program sectors, and we also attempt to minimize duplication of effort. Beginning in 1970, we undertook this coordination effort through a program structure which we call the federally coordinated program of research and development. We continually update this to reflect the most urgent problems which face State, local, and Federal highway officials.

The structure of the federally coordinated program provides a framework that we use to organize the research activities into five major categories: safety, traffic, maintenance and environmental management, pavements, and structures.

The federally-coordinated program is not a rigid structure. Activities are updated as old problems are solved and new problems arise. This is particularly necessary in a time when we are moving from a major emphasis on construction of new interstate highway facilities to a period of restoring and reconstructing the existing highway and bridge network.

When Ray Barnhart became the Federal Highway Administrator in 1981, he began to question the process which we used to develop the program, and he questioned the priorities in our administrative contracts. Under his guidance, we have undertaken several additional actions to improve the monitoring of the program.

We began like good businessmen. We asked our customers for advice. Our customers, in this case, are the States, acting through the AASHTO policy committee, and last year we asked the State highway administrators to comment on what they felt should be the Federal role in highway research, development and technology transfer, and also requested their recommendations as to which items should receive priority. Forty States responded to this inquiry. They gave overwhelming support to continue our current functions and they provided many positive suggestions, which were appreciated by us, and we have already begun to implement many of their suggestions.

Two other activities are underway which will affect the content and form of the program. The first will identify and justify a long-term component in the highway research program. In our opinion, highway research should not be confined to solving only today's problems. It must also anticipate and identify future needs in the highway system. In addition, there must be sufficient leadtime so solutions can be found before the needs reach crisis proportions.

Due to the urgency of some current operation problems and direction received from Congress and others, long-range research activities in our program have been somewhat reduced in the past several years. We still conduct some long-range work such as development of substitutes for binders derived from petroleum sources, the development of a noncorrosive replacement for salt as a deicing chemical, improved welding technology and flaw detection techniques, and several other areas. We are working on a plan to revitalize this long-range activity with specific budget proposals expected for the fiscal year 1985 program.

We also expect information from the strategic transportation research study which is being conducted by the transportation research board with our financial support and technical assistance. You have heard about this from earlier witnesses.

Our final effort in this area is an attempt to improve our communication with State highway agencies and others regarding research needs. We have recently established new procedures to solicit problem statements from States and major new project recommendations. The system is patterned on the way the States administer the national cooperative highway research program.

The final effort that I would like to mention briefly in our research management activity is technology transfer. Even though we feel the R&D program is responsive to our needs and produces valuable new technology, no benefits are gained until the technology is understood and adopted by State and local highway agencies. Therefore, we put considerable emphasis on transferring this technology, the results of the research, to the State and local customers.

The four areas which we used in this field include implementation, which is translating research findings into a form better understood by the operating official; experimental projects, in which previously researched material might be used in actual highway construction projects; demonstration activities, where research products might be promoted through actual demonstrations, including workshop training seminars, pilot installations at appropriate locations; and finally, training courses put on by an agency in the Federal Highway Administration called the National Highway Institute.

In addition, we are emphasizing new technology for local highway agencies. There are thousands of cities and counties in the United States which have bridge and highway responsibilities. Obviously, they should also benefit from our research findings. Although some States have historically provided technology and assistance to local agencies, many States have neither the mandate nor the resources to do so.

In the last couple of years we have selected 14 States in which we expect a designated center to serve as technology contact points for local units of government. These centers are expected to maintain a stock of new technology reports and other research findings, and will provide services to local agencies such as newsletters, advice on new technology available to solve specific local problems, and the presentation of short pilot training courses.

This concludes my prepared statement, Mr. Chairman. Mr. Wood and I would be glad to respond to any highway-related questions.

[The prepared statement of Mr. Lamm follows:]

STATEMENT OF DEPUTY FEDERAL HIGHWAY ADMINISTRATOR LESTER P. LAMM
BEFORE THE HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT
AND THE
SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS,
JUNE 16, 1983

Mr. Chairman and Members of the Subcommittees:

I am pleased to be here this morning to discuss highway research and development (R&D) activities and the efforts to implement the findings of the research program. Mr. Edwin Wood, Associate Administrator for Research, Development, and Technology (RD&T) is with me and will assist in answering your questions.

Background and Legislative History

Research was one of the principal missions of the first national highway program in the United States and is, in fact, the oldest continuous Federal highway activity. Highway research began with the establishment of the Office of Road Inquiry (ORI) in the Department of Agriculture in 1893. With the creation of this office, whose primary mission was to investigate the best methods of roadmaking and to assist in disseminating this information, a formal, organized research program began.

The first sustained fiscal support for highway research was authorized by the Federal Highway Act of 1921. The foundation for the Federal-Aid State Highway Planning and Research (HP&R) program was laid with the enactment of the Hayden-Cartwright Act of 1934. Under this Act, up to 1 1/2 percent of the funds apportioned to a State could be used for "surveys, plans, and engineering investigations."

The Federal-Aid Highway Act of 1944 added the term "research" to the phrase above, thus allowing the States to use their 1 1/2 percent funds for a variety of research purposes. Funds which were not used for planning or research reverted to the construction program. With the Federal-Aid Highway Act of 1962 came the restriction that the funds be used for planning and research purposes only. If they were not used within the availability period, the funds would lapse. The 1962 Act also gave States the option to use an additional 1/2 of 1 percent of their Federal-aid primary and secondary system funds for planning and research activities.

The Federal-Aid Highway Amendments Act of 1963 expanded the law to include "development" under the planning and research section. Congress intended development to be an integral part of the overall R&D program and this provision encouraged the States to take a more active role in the development phase.

The performance of highway R&D is currently authorized by Section 307, Research and Planning, of Title 23 of the U.S. Code (U.S.C.). The portion of this section applicable to the FHWA administrative contract and staff R&D programs states "(a) The Secretary is authorized in his discretion to engage in research on all phases of highway construction, modernization, development, design, maintenance, safety, financing, and traffic conditions, including the effect thereon of State laws and is authorized to test, develop, or assist in the testing and developing of any material, invention, patented article, or process."

Authority for Federally aided State R&D programs is contained in Section 307(c). This section, as amended by the Surface Transportation Assistance Act of 1982 (STAA), provides that 1 1/2 percent of the funds apportioned to each State under sections 104 and 144 shall be available for "engineering and economic surveys and investigations; for the planning of future highway programs and local public transportation systems and for planning for the financing thereof; for studies of economy, safety, and convenience of highway usage and the desirable regulation and equitable taxation thereof; and for research and development, necessary in connection with the planning, design, construction and maintenance of highways and highway systems, and for study, research and training on engineering standards and construction materials, including evaluation and accreditation of inspection and testing, and the regulation and taxation of their use." (Underlined items added by STAA.) The STAA also provided a minimum Federal share of 85 percent for this program.

The FHWA role in highway R&D has evolved with the changing legislation. Initially, the Federal Government had the major responsibility and resources for conducting research and disseminating the results. As the State research programs increased, FHWA provided a substantial amount of direct technical assistance to the States and conducted staff research in its own laboratories. In the past 10 years, the FHWA involvement has changed; the FHWA program has shifted to relying more heavily on the States to perform R&D and on administering contracts rather than direct FHWA staff research. Personnel allocations for the FHWA R&D program are shown in Figure 1. It should be noted that 44 of the positions currently allocated to RD&T are involved in transferring new technology to potential users, rather than conduct of R&D. This includes positions in the National Highway Institute, which was moved to RD&T in 1982.

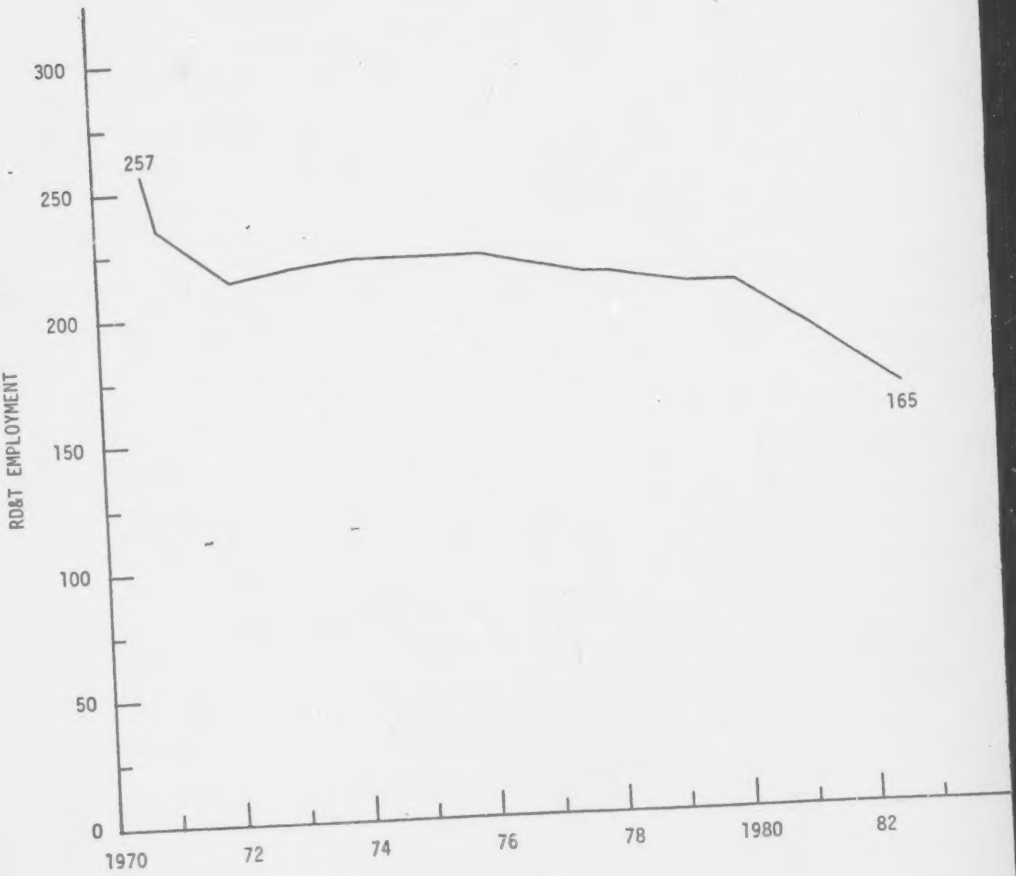

FIGURE 1

FHWA RD&T EMPLOYMENT

Current Programs

Federally assisted highway R&D programs will spend nearly $60 million this fiscal year and involve many organizations and people. All of the States and many localities receive Federal-aid or administrative contract funds for R&D. Highway research is performed by contractors, universities, associations, institutes, State highway agencies, other Federal agencies, and our own staff. We also work cooperatively with the Transportation Research Board (TRB) and with other elements of the Department of Transportation. Through cooperative agreements with foreign nations, international research results are also included in the R&D program.

Today, there are four major programs performing highway R&D. These are the HP&R program; the National Cooperative Highway Research Program, or NCHRP; the FHWA administrative contract program; and the FHWA staff research program.

The HP&R program is the cooperative Federal/State venture authorized by Section 307 of Title 23, U.S.C. The available HP&R funds are used by the States to finance a two-part program: Part I, Planning, and Part II, Research. The share allocated to research ranges from 5 to 55 percent, with an average of approximately 20 percent. This year the States have programmed $31 million, of the $151 million available in HP&R funds, for research activities. States initiate R&D studies to be conducted by their own staff or by contract with public or private research organizations. Universities and colleges do a substantial portion of the State HP&R research. The FHWA provides technical guidance and coordination, and reviews and approves both the overall program and the individual study elements.

The NCHRP is a three-way contract between the American Association of State Highway and Transportation Officials (AASHTO), the FHWA, and the TRB. Research activities are selected by a special committee of AASHTO, called the Select Committee on Research, and administered by the TRB, with approval by the State highway officials.

Under this program, 4 1/2 percent of the HP&R funds are pooled by the States on a voluntary basis for research which responds to the collective needs of State highway agencies. The FHWA, being responsible for the Federal-aid funds used in NCHRP programs, reviews contractor selection, program content, and determines when completed work has fulfilled the technical requirements. Program selection and composition are the prerogative of AASHTO and the participating State highway agencies, through the Select Committee. For FY 1983, $6.8 million is available for this program.

The FHWA now conducts a major portion of its own research and development work by contract as authorized by Title 23. Funding for this activity comes from the Highway Trust Fund and is reviewed, authorized, and appropriated annually by the Congress. These funds are separate and apart from the HP&R funds, and amount to $21.5 million this year.

Contract research is performed by private firms, universities, nonprofit organizations, individual consultants, other Federal agencies, and State highway agencies. This work is contracted under Federal Procurement Regulations and supported entirely by Federal funds. The FHWA funding may be supplemented by other agencies within DOT, such as the Urban Mass Transportation Administration and the National Highway Traffic Safety Administration, and by other Government agencies such as the Department of Housing and Urban Development, and the Department of the Interior, when these organizations have mutual interest in the research.

The final program, our staff research and development, is conducted by FHWA employees. While some of the staff R&D is devoted to continuing efforts in major problem areas, a significant portion is geared to quick-action response for immediate problems identified by the operating offices of FHWA.

Our staff research activities have recently been enhanced by the completion of a new research facility at our Turner-Fairbank Highway Research Center in McLean, Virginia. The new structure provides 80,000 square feet of laboratory, office and support service space. The light laboratories include a highway driving simulator, pavement components laboratory, experimental vehicle preparation area, highway communication and electronics laboratory, and a highway noise laboratory. New heavy laboratories in the building include a structural and a highway hydraulics laboratory.

Approximately 20 percent of total R&D employee time is spent conducting staff research. The remaining time is used to plan, administer, and monitor activities supported by Federal funds, including contract research, HP&R, and NCHRP. An important benefit of staff research is direct involvement with the latest technology, thus enhancing staff ability to manage research contracts and aid the States in the HP&R program.

R&D Budgets

Budget allocations for highway R&D are shown in Table 1. For FY 1982, the FHWA administrative contract allocation was $18.5 million or 0.22 percent of the total FHWA authorization. With the addition of the FHWA staff research and the funds allocated to R&D by the States under the HP&R programs, the total obligated for highway R&D was $40.3 million or 0.47 percent of the total Federal allocation for the highway program.

With the increased funds available from the Surface Transportation Assistance Act of 1982, the State allocations for R&D have increased from $19 million in FY 1982 to $31 million in FY 1983. In addition to the activities in the Federally supported HP&R program, some States supplement this program with additional 100 percent State funds. For FY 1983 the States have allocated an additional $20 million for planning activities and nearly $12 million for additional R&D work. In future years there is a strong indication the States will use the increased HP&R funds to finance many activitites previously covered with 100 percent State funds, that is, Federal funds will substitute for State funds. It should also be noted that the size of the research program in many States is constrained by the limited staff available to conduct or administer the State program.

Table 1

	FY '82[1]	FY '83[2]	FY '84[3]
Highway Authorization	$8.5B	$13B	$13.4B
FHWA Contract R&D	$18.5M (0.22%)	$21.5M (0.17%)	$23.6M (0.17%)
Total Highway R&D	$40.3M (0.47%)	$43.0M (0.34%)[4]	$48.7M (0.35%)[4]

[1] Actual Obligations

[2] Programmed Amounts

[3] Estimated Allocations

[4] Increased to $58.6M (o.46%) for FY 1983 and $65.1M (0.47%) for FY 1984 to reflect current State Work Plans and projected plans for the HP&R program.

Program Control and Coordination

The FHWA is responsible for coordinating the activities within the four R&D programs and minimizing duplication of effort. With over 1400 active studies each year, this could be difficult. In 1970, we created an overall national program structure to coordinate the many activities and plan the future work. This structure, designated as the Federally Coordinated Program of Research and Development (FCP) is continually updated to reflect the most urgent problems facing local, State, and Federal highway officials.

The FCP is not merely a system for classification and tracking of activities. Rather, it provides active leadership to focus the efforts of the many participants on the problems of current national interest. The FHWA research staff selects those aspects of such problems which can best be addressed by Federal contract or staff activity, and actively promotes Federal-aid studies on aspects which the States' research resources are in the best position to undertake. The States have experience with operational problems and a pool of research talent which cannot be obtained elsewhere, and often have effective cooperative arrangements with local universities for studies of highway problems. By this approach, the FCP serves to integrate the efforts of all participants, allowing common objectives to be achieved within the shortest possible time and at minimum cost. The involvement of the States also facilitates the subsequent step of technology transfer of research results into practice.

The structure of the FCP provides a framework for organizing the major areas and distinguishing the subelements of these areas. Thus, major program areas are classified into categories, each category is divided into projects, and each project subdivided into tasks. Individual studies within tasks are the smallest identifiable elements in the program.

The major areas, or categories, in the FCP are:

- Safety
- Traffic
- Maintenance and Environmental Management
- Pavements
- Structures

Work within these categories accounts for approximately 70 percent of the total highway R&D program. The remaining 30 percent of the R&D effort seeks solutions to problems of local, rather than national, interest, and is not included in the FCP.

Program Development and Priorities

The FCP is not a rigid structure. Activities within the program are updated as old problems are solved and new problems arise. This is particularly necessary in a time when we are moving from a major interstate highway construction program to a period of restoration and reconstruction of the existing highway system.

When Ray Barnhart became the Federal Highway Administrator, he questioned the process used to develop the program and priorities for our administrative contracts. Under his guidance, we have undertaken several actions to improve this process.

As a starting point, we acted like good businessmen; we asked our customers for advice. Acting on Administrator Barnhart's suggestion to the AASHTO Policy Committee, last year we asked all of the State highway administrators to comment on the Federal role in highway research, development and technology transfer, and requested their recommendations for priority work. Forty States responded to our inquiry. They gave overwhelming support for continuation of our current functions, and provided many positive recommendations.

- Over half of the respondents specifically cited and strongly supported our technology transfer activities
- Work in the pavement management area was noted as a priority by 23 States
- One-third of the States indicated the need for more State or other input (including TRB and AASHTO committees) to the FHWA RD&T program development and project selection process
- One-fourth of the respondents cited the need for research to support 3- and 4-R work, with cost-effectiveness as a principal focus
- Seven States specifically noted the need for FHWA involvement in basic or long range research, and
- Five States supported planning research related to highway finance and resource allocation

We appreciated this fine response from the States and have already started actions responding to their recommendations.

Last year when we were developing the FY '83 program, we asked our FHWA Pavement Management Coordinating Group, which includes representatives from our offices of Engineering and Highway Operations, Research and Development, Implementation and Planning, to review and develop new studies in the pavement area. There was good coordination among the research and operating office staff, and we were very pleased with the recommended program which resulted from this effort.

For the FY '84 program we expanded that approach, establishing Research Advisory Councils in the remaining areas of the FCP: Safety, Traffic, Structures, and Environmental and Maintenance Management. These Councils, composed of FHWA Headquarters and field office representatives, also coordinate with the appropriate TRB and AASHTO Committees, and others who can help keep our program responsive to the needs of the highway community.

After the individual Council recommendations are reviewed by top management in RD&T, the major activities in the entire program are presented to our Contract Review Board. This Board, chaired by our Executive Director, was created to assess individual requirements in the light of overall FHWA program priorities and to ensure the appropriateness and cost effectiveness of the methods used to satisfy program needs.

Two other activities are underway which will affect the content and form of the program. The first deals with how to identify and justify a long term component in the research program. Although it is tempting to do so, highway research should not be confined to solving today's problems; it must also anticipate and identify future needs in the highway system. In addition, there must be sufficient lead time so solutions can be found before the needs reach crisis proportions. Due to the urgency of some current operating problems and budget limitations, the long range research activities in our program have been somewhat reduced in the past several years. We have been able, however, to continue long range work on development of substitutes for binders dervied from petroleum sources, the development of a noncorrosive and environmentally acceptable replacement for salt as a deicing chemical, improved criteria for design of bridges to resist earthquakes and strong winds, improved welding technology and flaw detection techniques, certain aspects of accident analysis and skid resistance, and traffic flow simulation. We are actively working on a plan to revitalize and expand the long range activity and specific budget proposals for the FY '85 program to finance this activity.

We have already sought advice from our field offices, States and others in the highway industry, and developed preliminary topics for the long range research component. We are also anticipating good information from the Strategic Transportation Research Study which is being conducted by the TRB with our financial support and technical assistance. We believe this study will be very helpful in recommending priority work areas and appropriate resource allocation for the next several years. It is also expected some basic research needs will be identified through this study.

Our final effort in this area is an attempt to improve our communication with State highway agencies and others regarding research needs. We have recently established new procedures to solicit research problem statements and major new project recommendations from the States. The system is patterned on the successful process which is already used for the NCHRP. We will also use the Federal Register to seek wider input regarding our program and priorities.

Technology Transfer

The final effort in our RD&T process is Technology Transfer. Even though the R&D program may be responsive to our needs and produces valuable new technology, we do not reap any benefits until the technology is understood and adopted by State and local highway agencies. Our technology transfer program provides the special effort needed to bridge the gap which often exists between research and practice. To emphasize the importance of this activity, we have made technology transfer a management Empahsis Area in FHWA this year. This ensures special attention to technology transfer activities, both in Headquarters and in our field offices.

The technology transfer program includes four major activities with functions as follows:

> Implementation - Translates research findings into a form which is more readily understood by a practicing engineer or highway official. Using the research findings as a base, field tests and evaluations are often conducted in cooperation with the State highway agencies. If the technology proves useful in the field, user manuals, technical advisories, video-tapes and slide-tape presentations are developed to ease and promote adoption by the potential users.

Experimental Projects - Determines whether previously researched, field tested or documented materials, techniques or equipment can be adopted for use in highway construction. Experimental features are incorporated in Federal-aid highway construction projects to determine the suitability of the features as regular construction items. Results of the field evaluations are published in a National Experimental Projects Tabulation.

Demonstration Projects - Selects R&D products which can best be promoted through actual onsite demonstrations. The three promotional techniques used in this activity include hands-on demonstration, workshop training seminars and pilot demonstration installations at appropriate locations.

National Highway Institute Training Courses - Develops and presents training in new highway technology to State and local highway officials and their employees. Activities authorized by Section 321 of Title 23 U.S.C. include presentation of courses in "modern developments, techniques, and procedures relating to highway planning, environmental factors, acquisition of rights-of-way, engineering, construction, maintenance, contract administration, and inspection."

In addition to these special efforts to get new technology to State highway agencies, we are also emphasizing new technology for local highway agencies. There are thousands of cities and counties in the United States with bridge and highway responsibilities, and they could benefit from our work. Although some States already provide technology and assistance to local agencies, many have neither the mandate nor the resources to do so.

We have worked with the States and selected 14 locations to serve as technology centers or contact points for the local governments. The centers will maintain a stock of new technology reports and other materials, and will provide certain services to the local agencies. This includes newsletters, advice on new technology available for specific local problems, and presentation of short training courses.

This is a pilot program which will run for 2 years. At the end of the pilot phase we will evaluate the effectiveness of the program and, if warranted, will try to continue the program in the future. There is also a possibility the program may become self-supporting in some States.

Conclusion

Mr. Chairman, I have tried to give an overview of the four elements in the highway R&D program which is administered or financially assisted by the FHWA. I have described the FCP, our program coordination structure, and explained the several activities used to develop and update our administrative contract program. Finally, I have indicated the special efforts which are made to prevent research results from lying on the shelf, unused by the highway agencies. We believe our technology transfer efforts have been very successful, and our recent survey of the States confirms this belief.

This concludes my prepared statement, Mr. Chairman. Mr. Wood and I would be pleased to respond to your questions.

Mr. GLICKMAN. We thank you for your testimony.

I must mention that in the past my subcommittee has conducted some hearings on general oversight of Government surface transportation R&D. The last time we did this on a comprehensive basis was in March 1979. It is going to be my recommendation that—probably not this year, but next year—that we do an update of all of your surface transportation R&D programs, because I think that helps focus the attention on the issue.

Again, my subcommittee has jurisdiction over the research and development funds of the FAA, so it is kind of a curious mix here that we have. Mr. Swinburn stated that more than half, about $300 million of the DOT R&D budget, was devoted to efforts to improve the safety and productivity of the Nation's air traffic and air space system, of which this subcommittee has been a very active participant and a catalyst in that effort. But in fiscal 1984 the FHWA will have obligated $49 million for research in highway transportation, including infrastructure, and perhaps a total of $60 million will be spent in fiscal 1984 on all federally-assisted highway R&D programs.

Now, trucks carry 23 percent of all the revenue ton miles in freight traffic in the United States; air freight amounts to 0.2 of a percent of the total. Not diminishing the significance of the air side of the picture, because the Government has a historic and unique role in promoting air safety—that has been a unique Federal responsibility—but passenger miles by air amount to slightly more than 200 million each year, the public drives approximately 1.3 billion miles per year. Yet your 1984 funding is five times higher for air transportation than it is for surface transportation. And yet the total Government expenditures for surface transportation are well in excess of what we spend for the aviation system.

So I guess my question to you is, not should the air space moneys go down, because Congress will not tolerate that, but shouldn't the percentage of dollars spent on roads by the Federal Government be shifted a bit to get more into the R&D side of the picture?

Mr. SWINBURN. First let me say, Mr. Chairman, that we completely agree with you, that the air space funds should not go down. We think the Congress and the Department have worked extremely well together in laying that program out and in deciding how much should be spent on R&D.

On the question as to whether we should be spending more money on R&D in the highway area, which is a very relevant question, particularly at this time when we're going through a major shift from new construction to preserving and rehabilitating our highway system, I am not afraid to admit, and I think you would find all of us not afraid to admit, that perhaps we should be spending more.

The FHWA, as Mr. Lamm laid out in his testimony, has been going through a great deal of analysis and research on that very question. We have asked the transportation research board formally, at our suggestion and with our money, to look at what direction we should be taking in our highway R&D funding in the future. We are beginning to get results from that effort.

The FHWA has had a series of other efforts underway, consulting with the users of these funds, the States and local authorities, the people that actually do the work and from whence the money comes. I think they will be prepared very soon—probably in the context of the fiscal year 1985 budget, although if it turns out we are able to reach conclusions with the TRB and the users before that, we would not be afraid to come back and ask for some reprograming in the fiscal year 1984 budget—to address the question. It is a very valid question and we think you are asking it at the right time. The answer may well be yes, we should be spending more and we should be spending on some things differently or with greater emphasis.

Mr. GLICKMAN. Go ahead, Mr. Lamm, because I want to follow up.

Mr. LAMM. Mr. Chairman, let me just amplify that.

I might mention that I have served as Executive Director and Deputy Administrator at the Federal Highway Administration for 10 years this month. During that time, I have come to Congress with support information for ten annual budgets for the Federal Highway Administration. I must say, if this committee comes in and tells the Federal Highway Administration we should be spending more on research, that would be a change from any congressional advice we have had previously, because the appropriation committees, without fail, have cut our research proposals each year. Also during that same time we were unfortunate enough to be singled out by two of the golden fleece awards, and they seem to draw more adverse attention toward the research program than any beneficial result of, let's say, a successful finding, of which we produced several hundred during that same period of time.

Mr. GLICKMAN. Let me go back for a minute because I want to hit on what you both said.

What you are saying is, you have asked the Transportation Research Board, together with the States and others as well, to basically come up with a new plan on research—maybe that's an overstatement—but to give you some redirections or ideas on where research dollars ought to be spent in connection with this new effort to rehabilitate our Nation's highways and bridges. In connection with that effort you will be coming back to the Congress with modifications of your previous budget proposals and plans with respect to research programs. Is that correct?

Mr. LAMM. The Transportation Research Board activity, of which we were both speaking, is the item that Mr. Deen, who is Executive Director at TRB, testified to the committee about. Our intent there is to use the transportation research community, both the private sector and other government levels, to give us advice, and if the advice comes in saying that there should be a sizable increase in the amount of funding directed toward research, then, as Mr. Swinburn mentioned, we would certainly consider a reprograming request as early as the fiscal year 1984 budget.

However, I should mention that the initial emphasis that Tom Deen's activity seems to be pointing out is that we can make a lot more productive use of our current research budget by consolidating the Federal, State, and private sector funds in a more concerted attack on a smaller number of more productive problems. I think that is a very effective approach and we are certainly committed to working with TRB on that.

Mr. GLICKMAN. Right now, what would you think that consolidation would be focused on, what things would you be doing more of and what things would you be doing less of?

Mr. LAMM. In my statement, and I am sure in Mr. Deen's as well, we both reflect that we don't really know enough about the basic properties of asphalt. And while asphalt has been used as a road-building material for many years, we may be even asking field engineers to make the wrong tests on asphalt. It may not show the proper physical attributes that produce long-life pavements. It may well be that again we, at the Federal level, along with the State and private sector people, will refocus some of our research dollars and try and concentrate more effectively on that basic longer-term problem.

Mr. GLICKMAN. On reprograming, let's say you do come in, Mr. Swinburn or Mr. Lamm, and you have an internal feeling that you ought to be either reprograming or redirecting more funds in certain areas. Under the Surface Transportation Act, do you have authority to move funds out of the construction side into the R&D side?

Mr. LAMM. No, sir, we do not. The shifts we would make would be within the contract research budget, which at this point is very close to being approved by the Transportation Appropriations Subcommittees. In our testimony on that contract program, we furnished the appropriations subcommittees a makeup, a split, of how that contract funding would be broken down.

What we are saying is, if it turns out we take some of our previously anticipated funding and redirect it into a greater amount of attention toward the asphalt research area, we would need to notify the appropriation subcommittees of this. But we don't have the option of taking funds that are made available by formula to the States for construction and reconstruction and use those funds on research.

Mr. GLICKMAN. Some of the witnesses testified that the problems concerned not so much the money but the operational and organizational structure of governments generally. I have said before that the road-building industry, in relationship to Government, is probably more like the defense industry than any others, because it is almost all Government expenditure, whether State, local or Federal, and you're dealing with a limited group of contractors.

DOT staff suggested some reorganizations in 1981 and recently the President's Private Sector Study Commission on Cost Control recommended some reorganizations within the Department.

Do you have any comments on what's being done with any of that? Does it affect the operational efforts of research? Do you folks deal with the people who spend the bucks, who transfer it back to the States? I am interested in the management of these research programs, how they would relate to the operational side.

Mr. SWINBURN. The private sector survey's recommendations, Mr. Chairman, were threefold. First, they recommended there be within the Office of the Secretary a more centralized policy focus on R&D around the Department. Second, they recommended a structure within the Office of the Secretary to accomplish that end. Third, they recommended a greater involvement by the private sector in determining the direction of the R&D programs within the Department.

Those recommendations are presently before the Secretary, as are all of the recommendations made by the private sector survey team, which go well beyond R&D. She will, I think this week, be responding to the White House with her thoughts on the matter.

I can say that the recommendation that there be more policy oversight within the Office of the Secretary of the Department's R&D is looked upon favorably, not just by the Secretary but by those of us who advise her and by the modal administrations. She is probably going to move to put in place a structure within the Office of the Secretary to accomplish that.

The alternatives she is evaluating range from something that might be called a science advisor, if you will, an expert person with a small staff, to a more elaborate structure of the type recommended by the private sector survey. I think we probably will try to stay away from the elaborate structure, feeling that the decentralization of our Department has worked fairly well in the past and we should try to avoid layering in a new bureaucracy between the Secretary and the users of the administration's R&D funds.

We are also very sympathetic to the third recommendation, that we should involve more of the private sector in the Department's decisionmaking processes. I should say not just private but the other public sector bodies, the States. I think FHWA has been doing a lot of that in the last couple of years under Administrator Barnhart and will do more. We are looking at the specific recommendations that were made on how we do that procedurally and have not yet made a decision.

Mr. GLICKMAN. Let me just followup.

Several witnesses have stressed that a major impediment to effective research, especially long-term research, is top management attention and turnover in top policy management, both in appointed and elected officials. I think probably the record would show there have been a number of DOT Secretaries, Deputy Secretaries, FHWA Administrators, Deputy Administrators, and Assistant Secretaries for Policy, since DOT was established in 1967. The turnover may be less or more than in other cabinet level departments, but if we had all these names for the record, there would probably be a significant list of people.

My question is, How do we have any long-term policy on research if the average tenure of decisionmakers is very short?

Mr. SWINBURN. We would like to give you a twofold answer to that, sir. It is correct that there has been a lot of turnover in the Department. I have been there for 12 years and I'm working for my seventh Secretary at this point.

Mr. GLICKMAN. Congratulations.

Mr. SWINBURN. And it is exactly that situation——

Mr. GLICKMAN. Mr. Lamm has been there for a while, too, I think he testified. You have been in the Department for a long time, too, haven't you?

Mr. LAMM. Yes, sir. In fact, I was going to mention some personal comments on the Federal Highway Administration after Mr. Swinburn's comments.

Mr. GLICKMAN. OK, go ahead. I'm sorry.

Mr. **Swinburn**. It is that kind of turnover that I think leads to positive consideration by all of us of creating an institutional focus within the Office of the Secretary of the type recommended by the private sector survey.

Again, we think the focus should be there, and I am sure the Secretary will create some organization to respond to that. I doubt if it will be as complex an organization as has been recommended by the private sector survey.

I should note that yes, there has been a lot of turnover at the highest political levels, again, the Secretary and the deputies. But I have been there for 12 years, and Mr. Dugoff has been there for 10, and Mr. Lamm forever——

[Laughter.]

Go ahead with your comments.

Mr. **Lamm**. With regard to the highway program, Mr. Chairman, I have worked for the Federal Highway Administration since 1955, and as I mentioned, for the last 10 years I have been in a position of administrative responsibility in the Administrator's office, so that certainly within the highway program we have had a great deal of continuity. In fact, I would step up and take very much of the blame that anyone wants to put on the Federal Highway Administration for anything that went on during the past 10 years, because I was involved——

Mr. **Glickman**. I wouldn't do that, Mr. Lamm. We could find some——

Mr. **Lamm**. I might mention that during that period of time it has been my pleasure to work with several transportation secretaries in the State of Kansas and the State of Tennessee.

Mr. **Glickman**. Your current Secretary has a Kansas connection, too. [Laughter.]

I would just make a final point. There are several questions that I would like to ask you which have some technical specifics to them, concerning some of your current programs. They are too technical to ask now, so I would like to be in a position to write you with those questions and be able to get a response. Mostly they have to do with the status of certain research projects that were not detailed in your testimony, and maybe giving some historical background. So we will be supplying those and would appreciate your response for the record.

Mr. **Swinburn**. Yes, sir, we would be glad to respond.

Mr. **Glickman**. Mr. Dugoff.

Mr. **Dugoff**. Mr. Chairman, I wonder if I could try to get a lick in on the last question, too, just a brief one.

Mr. **Glickman**. Sure.

Mr. **Dugoff**. Without by any means attempting to take issue with your implied suggestion that the extent and nature of turnover at high echelons in the executive branch cuts against the likelihood of a long-term perspective in R&D planning, which I agree is a generic problem in the Federal Government, I would also like to elaborate on a point that Mr. Lamm made earlier. That is as much as it is the tendency of executive branch management to exert pressure toward a short-term perspective, I believe the Congress, in general, or at least that community of Congress that has been most influential in our Department's appropriations process, has exerted the same type and I think a more influential force in that direction.

So to the extent that this committee could constitute a countervailing force in the interest of a longer-term perspective, you would be serving our programs very well, indeed.

Mr. GLICKMAN. I think that is a useful comment.

Mr. Gore.

Mr. GORE. In that regard, what we are really engaged in here is research and development on research and development, and we hope to find out how we might more productively exert that counterpressure, because we really believe we can end up saving the taxpayers a lot of money by putting a more coordinated and better focused effort into this area.

I welcome some of the comments that you all have made in response to the questions. I find them quite encouraging. I don't know how much encouragement to take from them, however. Assuming that we can convince our colleagues on the Appropriations Committee that this is an area where we are being penny wise and pound foolish, I am not sure that other parts of the administration are really responsive to the way of thinking that is evident in some of your responses here.

As an example, I find a stark contrast between some of your responses and your prepared statements. I asked Mr. Pewitt about OMB. Did any of you all have to get your statements reviewed by OMB?

Mr. SWINBURN. Yes, sir. It is standard procedure that all our statements be reviewed by OMB.

Mr. GORE. Were there substantial changes?

Mr. SWINBURN. I don't believe so, Mr. Chairman.

Mr. GORE. Well, all right. That is never a useful line of questioning anyway. You never get a full response and that's always understandable.

Mr. Pewitt said the ball is in your court, and you have got to present a good plan. You have said that you hope you're going to come up with one soon. Is that essentially correct?

Mr. SWINBURN. That's correct, Mr. Chairman.

Mr. GORE. When?

Mr. SWINBURN. As Mr. Lamm noted in his prepared testimony, things would seem to be on track for making proposals in the context of the fiscal year 1985 budget.

Mr. GORE. Next January?

Mr. SWINBURN. Formally submitted to Congress. Of course, within the administration, that gets put together over the next 6 months.

Mr. GORE. Well, I am going to ask that the staffs of our subcommittees, at least of mine—and I assume our cooperative efforts will continue—remain in close touch with you all as that process continues.

There are some really obvious things that need attention. Some examples that were given to us included research into a deicer or a snow removal chemical that didn't destroy the highways. Does that make sense to you, too?

Mr. LAMM. Yes, sir. We have research going on, and either Mr. Wood or I would be glad to comment further to the committee about the status.

I might mention that at present we know of a material that would be a substitute for deicing materials in certain areas where environmental problems are really severe. The only reservation that some State and local officials would have is that substitute material costs an awful lot more——

Mr. GORE. It's expensive.

Mr. LAMM. Yes, sir.

Mr. GORE. Again one of the principal goals of research is to find ways to break that tie between expense and durability and find ways to do it more cheaply.

We have also heard that there are a lot of incentives in the private sector that work in the opposite direction, and that when bids are solicited the durability dimension is not really taken into account. Therefore, you don't get competition on the basis of durability, which would presumably lead to enhanced private efforts to come up with some sort of breakthrough.

Do you agree that that's a serious part of this problem?

Mr. LAMM. I haven't been attending all of your hearings, Mr. Gore, and I don't know of the particular comment that led to your question. But I would be glad to amplify a response for the record.

Mr. GORE. I am talking about the low-first-cost bid emphasizing the front-end cost, without taking into account how long it is going to be before the thing has to be done again. In other words, ignoring the life cycle cost.

Mr. LAMM. Well, in that case, I would characterize the Federal Highway Administration's intent as being one of working with the States to make sure that there are alternate materials or processes available for a given product, the obvious one is pavement surface, but there are also available alternate options in the case of such things as bridge construction materials, sign face materials, and many other characteristics of roadside hardware.

It is our desire and intention that the States do go through life cycle costing. Again, if those comments were the result of testimony from representatives of the asphalt and/or cement industry—life cycle costing is an operation that is an art rather than a science, and also the basic material cost would vary from one part of the country to another. We know that in a comparison between asphalt and portland cement concrete pavement the basic material costs vary widely if the particular proposed highway happens to be located near a cement plant, or if the material has to be shipped in for a long distance. So a life cycle cost estimate may well come up with different proposed materials in different parts of the country for use in different purposes, but again I would say our desire and our intention is to have the States work through a life cycle cost selection process.

Mr. GORE. If your desire and intention is for them to do that, why isn't that expressed in the regulations and in your formal procedures?

Mr. LAMM. It is expressed, but it is expressed in a less-than-mandate fashion, Mr. Gore, because for one thing——

Mr. GORE. Is that not being done at all?

Mr. LAMM. No. I can accept someone's challenge and go out and look at an individual State or an individual project, but across the board, I can't accept that statement. We have been pushing the concept of value engineering, which is just exactly the evaluation of a number of different alternate material sources or types through the design process. We don't, however, require every State to conduct value engineering on every project. There is the fact that in many cases the States know better than we what works in a given area of the country and we don't impose that requirement on every State for every project.

Mr. GORE. OK. I also have some questions in writing for the record, if you all would be willing to respond to them in writing.

You mentioned the new facilities at the Turner-Fairbank Research Center in McLean. A witness last week said that the new building is a fine thing but, if there is no detailed work plan for its use, it is just a waste of money.

Do you have a 2- or 3-year work plan prepared to utilize the increased capabilities at the center?

Mr. WOOD. Yes. The center has just been opened, of course, we haven't been able to get into our lab facilities because the contractor is still doing his finishing touches. But over the next 6 or 8 months we will be getting the labs operational. We do have a driver simulator which we plan to use quite effectively in the highway safety area; a structures lab, which is one of the two in the United States I think that are available for full-size testing of girders or structures; and a hydraulics lab which probably will be operational in January.

But we will be looking at our budget for 1984 and 1985 to start effectively utilizing the facilities that we do have out there, and we expect we will put them to proper use.

Mr. GORE. What major activities are scheduled in the next several months?

Mr. WOOD. For the lab facility?

Mr. GORE. Yes.

Mr. WOOD. Basically, the first lab which will be operational is the driver simulator. This device will actually enable us to have a person sit in a car and simulate driving down the road and get the reactions to, say, signing or geometric design. This operation will be on line in the next 60 to 90 days and we will be probably expending financial resources in the driver simulator and having a contractor come in and operate the equipment with our guidance.

Mr. GORE. What is that designed to do?

Mr. WOOD. It is to actually, in a safer way, do research relative to driver reaction. Instead of taking them out on the road——

Mr. GORE. How drivers react to——

Mr. WOOD. [continuing]. Geometrics, sign recognition, guidance markers, edge line striping.

Mr. GORE. Incidentally, I remember vividly, when I was young, my father—to whom I don't often refer to in hearings—but he was the author of the Interstate Highway System Act in the U.S. Senate. I remember vividly as a young boy, 9 or 10 years old, sitting in the hearings when they selected the design, the width and all that.

I remember sitting there the day when the color green was selected for the interstate highway signs. I don't remember it being on such a scientific basis as having it simulated, but I think they did have some scientific basis for that.

Anyway, what other activities are scheduled in the next few months?

Mr. Wood. Really, we are not underway. The dedication just took place on May 5 and we have just moved into the office complex, so our lab facilities probably will not be going until the next fiscal year.

Mr. Gore. Until October?

Mr. Wood. Well, probably next spring before we get it all underway.

Mr. Gore. So not much is going to happen until next spring?

Mr. Wood. Except in the driver safety area, yes.

Mr. Gore. You say you have a plan. What's in the plan?

Mr. Wood. We can provide it for the record. It is part of our——

Mr. Gore. Just give me some of the major components, if you can, major activities that make up the plan.

Mr. Wood. Our hydraulics lab, for instance, we would be interested in the efficiency of inlets on scuppers for structures, inlet design, so that it is the most efficient and doesn't cause a problem with, say, bicycles, the safety aspects of the grid. If we have a longitudinal slot in the inlet, it might be a problem to the bicycle, so if you were to redesign it and still have an efficient system——

Mr. Gore. The inlet of what?

Mr. Wood. For a drainage system alongside the highway.

Mr. Gore. When is that project supposed to start?

Mr. Wood. I was just citing that as an example of what might be tested in the facility.

Mr. Gore. Sort of as a hypothetical?

Mr. Wood. Yes.

Mr. Gore. Well, I am trying to get the major components of the research plan. What would be the major components of the research plan?

Mr. Wood. I think I had better provide that for the record. I need to do some research on that.

Mr. Gore. I see.

But there is a plan?

Mr. Wood. Yes.

I should explain a little bit my background and it might help the committee. I am rather new to the R&D effort. I have been in the R&D operation about a year and a half. Basically, I have been putting my attention on the reorganization. The information that Mr. Lamm gave to you earlier in his testimony relative to inquiring of States as to where the R&D program is going, not only with them but with us, how they view what we're doing, whether we're being attentive to their needs and the real world problems.

The technical aspect of our program, as Mr. Cole is aware, we have our office director. We have three office directors and a science adviser to assist me with the technical plan relative to the utilization of the facility and our overall research plan.

Mr. Gore. Well, you'll forgive me if I say I am not reassured about the preface to my original question, recalling the statement of a witness last week who said the new building is a fine thing, but if there is no detailed work plan for its use, it is a waste of the taxpayers' money. I would welcome the opportunity to see in the record of the hearing a detailed work plan as to how you plan to use this new facility.

Does your plan include any research on asphalt or cement or road surfaces?

Mr. WOOD. Some of our major research in that area, as Mr. Lamm explained, was in some substitute materials. We are very much concerned about the asphalt, whether we will actually have asphalt available in future years. We worked on a sulpher extended asphalt material, and we also have worked on "Sulphlex", which I have an example here today that I could show you.

These materials are not at the present time cost effective. Crude oil would have to be $40 to $50 a barrel range before they would be cost effective. However, we also understand, or it's our feeling anyway, that refineries are getting more and more efficient and are giving us less and less of an asphalt byproduct, and that could create a product problem.

Mr. GORE. Let me come back to my question then.

Do you have any effort in that area as part of your research plan in this new facility?

Mr. WOOD. The asphalt and the Sulphlex is actually being done in the old facility next to it. But yes, sir, there is research going on in the Sulphlex and sulphur-extended asphalt. We are presently demonstrating it out in the real world. I think we have six or eight States who are participating with us and we are actually laying this material down and watching it work over a number of years to determine whether it is actually giving us a viable product.

Mr. GORE. Do you have any other road surface research at the new Turner-Fairbank facility?

Mr. LAMM. I judge from the nature of the questions, the direction of the questions, that I think someone may have given the committee the misapprehension that until this new building was built we had no lab. We have had lab facilities in McLean that physically date back to 1940——

Mr. GORE. No, I understand.

Mr. LAMM. There has been staff work going on.

Now, your last question, Mr. Gore, the direction of pavement research is going to be one of the sizable staff activities. There is now in the old building some laboratory research on pavement——

Mr. GORE. Is that going to be done—Is any such research going to be done in the new center?

Mr. LAMM. Yes, sir. The intention is most of the existing laboratory space will be transferred to the new building over the next several months. In addition, we are going to have new capabilities that we don't now have. I think that's what we were trying to leave you with in previous answers, trying to get into some of these new facilities.

Mr. GORE. Well, I hope you can provide for the record relatively soon the detailed work plan prepared for the increased capabilities of the research center. The taxpayers spent a lot of money on this center and we would like to see that plan.

[Referenced material appears in the appendix]

Mr. LAMM. I would repeat again the suggestion I made earlier, too, Mr. Gore, that we would be more than glad to give either the committee members or your staff a guided tour of the facility and talk about the labs themselves.

Mr. GORE. We would appreciate that, but we want a guided tour of the research plan first and we're having trouble getting that.

In 1956, the large-scale testing of the performance of pavement and bridge structures, known as the AASHO road test, was authorized. Construction of the test facility was completed in 1958, and testing was continued until late 1960. This one large-scale project was supported by all of the then 48 State highway departments, the Federal Bureau of Public Roads, the Automobile Manufacturers Association, the Petroleum Industry, the American Institute of Steel Construction, and the entire cement, automotive, and steel industries. The cost of this single large-scale project was $27 million.

According to the witnesses we have heard in these hearings, we are still using the results and findings coming out of that project. It was extremely beneficial and has saved untold hundreds of millions of dollars, perhaps more, since then.

Now, an equivalent scale of the project today would cost more than $90 million in 1983 dollars—and I make this reference for purposes of comparison. We had foresight and vision and saved the taxpayers some money and improved the productivity of this country back in 1958, 1959, and 1960. But something on that order of magnitude would be $90 million today.

But according to your testimony, the total expenditure next year on all federally assisted highway transportation research will be only two-thirds of the cost of that single research effort back in the late fifties. I can imagine the reception in the DOT budget office and the OMB and the appropriations committee of a single highway R&D project costing $90 million being proposed tomorrow.

It is just unfortunate, however, that we have had in the last 25 years this extreme fragmentation and deterioration in our research management on highway R&D, to the point where the kind of visionary proposal that had such a tremendous payoff back in the late fifties and early sixties would just be laughed out of the Government today is just totally unrealistic. What we really want to do is find a way to get back to a coordinated focus, a sensible, organized, coherent approach to Federal highway and bridge R&D. I hope that some of the suggestions that you hinted would be forthcoming are, in fact, forthcoming.

This is not a partisan matter. You have seen from these hearings that everybody recognizes the money to be saved and productivity to be gained, and we stand willing to work with you and, in fact, are going to pursue this vigorously. We hope you will respond with some real constructive suggestions, a detailed plan, a good focus. You heard the OSTP witness say that they are awaiting a plan. Take them up on that, and take us up on it, will you?

Mr. LAMM. Yes, sir.

In fact, let me just mention, Mr. Gore, one of my early assignments was on that AASHO road test back in 1959. It was needed at the time because it was undertaken just shortly after the initiation of the interstate system, and I am aware of your father's role in that, as well as our predecessors, including Frank Turner, for whom the new laboratory is named.

At that time there was no standard way of designing highway pavements around the country. What the ASSHO road test led to was an approved standard guideline for the design of either concrete or asphalt pavements that was accepted by the Bureau of Public Roads and by all the States. We now have that in place. In fact, we are in the present cycle of going through a revision of that. But we don't need another major ASSHO road test to find out how to modify that design manual.

I might also mention, though, that once that research activity was completed the effort that the Federal Highway Administration, or the Bureau of Public Roads in those days, had in research went immediately down to a much lower figure. For instance, about 20 years ago in the early 1960's we administered a $3 million research program with no contract activity at all. We were trying to do the entire highway research responsibility through our own staff. Now we have a $25 million activity where we have more than $20 million of contract programs out and enlisting other people in helping solve these problems.

Mr. GORE. But, Mr. Lamm, here's the point. That effort was begun at precisely the same time that the country began its enormous investment in the interstate highway system.

We are now at a very similar point in time. We are beginning a big, new wave of expenditures, enormous in scope, focused on repair and maintenance. It is appropriate and sound Government policy and good judgment to do the same thing this time as we begin this enormous expenditure, a whole new effort comparable to the interstate highway system's beginning. It is appropriate for us to have a focused, comprehensive research effort at the beginning of that wave of expenditures, to tell us how to maximize the benefits from those expenditures and avoid some of the mistakes which research can help us to avoid.

Yet, as we confront this wave of expenditures, what we have, instead of a focused, sensible effort, is just a collection of uncoordinated, unfocused, projects here, there and everywhere that aren't tied together, that aren't part of a plan, that don't look at all the elements of the effort that need attention. It is up to you guys to get us from A to B. I hope you can do it. We're going to stay right on top of this.

Mr. LAMM. You sound to me, Mr. Gore, exactly like Administrator Barnhart did shortly after he came on board 2 years ago, and that is why we are working with TRB and the States and trying to do just what you're suggesting.

Mr. GORE. Well, not many results have been apparent yet, but we will suspend final judgment on that.

Thank you, Mr. Chairman. I have enjoyed this set of hearings. I think they have been productive and we will look forward to your additions for the record.

Mr. GLICKMAN. Thank you, Mr. Gore.

I would mention that this is the last day of hearings today, but I think we may want to hear from another group of people, the users of the roads. The automobile manufacturers spend a lot of money on research—again, a lot of it is to put a little voice in the computer of the car to tell you your door is open—but I'm not sure that they shouldn't have a statement here, perhaps as well as others who are users, and maybe some of the road contractors, construction people who are actually in the process of doing the work.

But I agree with Mr. Gore. We're talking about spending billions of dollars in a major national effort to rehabilitate our highways. It is every bit as big as the national effort to build the interstate highway system. We should have a way of doing it more efficiently while also improving safety. I think to do that requires a greater enhancement of your efforts on the research side of the picture.

So we are going to continue to monitor DOT's research activities, perhaps with generic hearings next year. I think that I, myself, and maybe Mr. Gore and others, will talk personally with Secretary Dole about this as well. We appreciate the fact that you have taken time to be here.

Mr. GORE. Just for the record, in closing these hearings, I want to compliment the staff for what I think has been an extraordinarily good job, and Dr. Leon Cole from the Library of Congress who has helped us to focus this effort and, as I said before, we're going to have to continue it.

Mr. GLICKMAN. Thank you.

[Whereupon, at 11:35 a.m., the subcommittees were adjourned.]

APPENDIX I

July 5, 1983

Honorable Dan Glickman, Chairman
Subcommittee on Transportation,
Aviation and Materials
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

The Portland Cement Association is taking this opportunity to amplify and extend the testimony I presented at the June 15 public hearing. We respectfully ask that this letter be made a part of the hearing record.

As the nation embarks on an expanded national highway program, we believe that the public interest will be served by a thorough examination of the basic engineering and economic issues that affect how well our highways perform, how long they last, and how much they cost.

We strongly support the principle of life cycle costs as the basis for giving the taxpayer the best service for the dollar. However, to make accurate life cycle evaluations, more performance data are needed.

Specifically, we urge that your committee consider including in its recommendations the following:

- Increased engineering and historical research by state highway agencies to determine objectively the relative performance, maintenance records, and costs of various highway designs.
- A national research program to determine, on the basis of performance data obtained as noted above, how best to build highways to meet specific traffic and service requirements.

Our industry welcomes the opportunity to comment further on the subject of your deliberations. Please let us know if we can help in any way in advancing the work of your committee in these matters.

Sincerely yours,

WJY/glw

THE
ASPHALT
INSTITUTE
EXECUTIVE OFFICES AND RESEARCH CENTER
Asphalt Institute Building | College Park, Maryland 20740 | Telephone: 301-ASPHALT (277-4258)

June 24, 1983

The Honorable Albert Gore, Jr.
Chairman, Subcommittee on
Investigations and Oversight
and
The Honorable Dan Glickman
Chairman, Subcommittee on
Transportation, Aviation and Materials
U. S. House of Representatives
Committee on Science and Technology
Suite 2321 Rayburn House Office Bldg.
Washington, D.C. 20515

Gentlemen:

Reference is made to testimony given to the Subcommittee on Investigations and Oversight and the Subcommittee on Transportation, Aviation and Materials during hearings on June 15 and 16, 1983.

During the testimony on June 16, a statement was made that a less than adequate supply of asphalt will be available in two or three years. This statement is contrary to the best information we can obtain from asphalt refiners. Contact was made with producers throughout the United States with a unanimous reply that asphalt is now and will continue to be available.

In support of this view, some refinery production is being shifted towards greater asphalt yields in light of the demand with some refineries being operated primarily for the purpose of producing asphalt. At this time, asphalt is considered to be nearly the only growth market in the petroleum industry and resources are being funneled in that direction. Substantial funds are being spent by portions of the industry in order to research and develop means for greater yields of asphalt from available crude oils as well as for design systems to further process residuals.

Oil refineries have traditionally scheduled crude acquisition and production on the basis of demand for the "light ends." More and more the availability of crude oils is shifting to the so-called "heavy crudes" which contain much larger percentages of asphalt. There is no

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shortage of these "heavy crudes" in the world supply. In addition, while a number of refineries have shut down in the recent past, the remaining ones are operating at only two-thirds capacity. These and other pertinent facts were reported by producer representatives to the Transportation Research Board Committee A2D05 in March 1983 and the minutes from that meeting can be procured from Mr. Tom Deen, Executive Director of the Transportation Research Board. Due to the inability to forecast the passage of the 1982 STAA and, consequently, the exceptional asphalt demands it generated, there could be localized shortages in the latter part of this summer. However, they should be of short duration.

Member Companies of The Asphalt Institute have stated repeatedly during previous periods of uncertainty, such as the oil embargo of 1974 and the more recent Iranian revolution, that asphalt would be available. Their statements were borne out and their present position on supply is no less firm. Raw materials are abundantly available as is refining capacity. With the exception of the supply problems previously mentioned and with the demand now being recognized, future asphalt supplies should be sufficient.

Respectfully submitted,

Gerald S. Triplett

Gerald S. Triplett
President

GST:nw

cc: Mr. Lester P. Lamm, Deputy
Federal Highway Administrator
Board of Directors, TAI

THE TEXAS A&M UNIVERSITY SYSTEM
TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843

OFFICE OF THE DIRECTOR
Area Code 713
Telephone 845-1711

June 16, 1983

Congressman Dan R. Glickman
1507 Longworth
House Office Building
Washington, D.C. 20515

Dear Congressman Glickman:

I appreciated the opportunity to present testimony before the joint hearings of the Subcommittee on Investigations and Oversight and the Subcommittee on Transportation, Aviation and Materials on Wednesday the 15th. I am sure that these hearings will be highly useful to Congress in addressing the role and adequacy of research in the transportation infrastructure. Under separate cover I am sending the Committee staff some additional statistical information that was requested following my testimony.

I would also like to bring up another situation that I feel was too specific to be included in the discussion, but one that is having a substantial impact on the research that is being conducted. Throughout the hearings the theme of excessive fragmentation, many small projects, and the lack of longer-range multidisciplinary programs to address major problems was repeated. Many Universities have organized Transportation Research Centers or Institutes as a mechanism to bring the various disciplines together to address these longer range, more complex problems. (Please see attached letter from Mr. Wood, Associate Administrator for R&D, FHWA.) They are now being forced out of the research programs of FHWA through interpretations of the set-aside requirements of the Small Business Innovation Act.

The interpretation followed by FHWA and its assigned SBA representative appears to be that the Agency is required by law to conduct at least as much research with small business firms in the current year as was conducted the previous year. Because of the small budget and fragmented programs, FHWA has traditionally awarded a high proportion of its contracts to firms who qualify as small businesses. According to the Procurement office of FHWA, 40 percent of their research went to small business firms in FY 1982 - 12 percent in set-asides and 28 percent through competitive procurements. In order to assure that at least 40 percent of the volume is let to small business firms this year, FHWA policy is to treat each procurement as a small business set aside if as many as two small firms have stated that they have technical expertise in that research area. The burden of proof is then on the technical staff to have the procurement removed from the set aside category. This process is apparently so onerous that the staff has all but given up fighting for open bidding.

The adverse consequences of this are two-fold. First, it forces the research agencies with multidisciplinary capabilities, who have the personnel and expertise to conduct the more complex, multidisciplinary research, out of the market. Eventually, this research capability will be dissolved. Secondly, if this process continues, it will force the agency to tailor its procurements to meet the capabilities of the small business community, thereby exacerbating the very fragmentation process that we need to overcome.

The Council of University Transportation Centers is an organization of those Universities who have developed organized Transportation Research Center or Institutes to allow them to bring the wide range of talents and disciplines in the University together to address transportation problems. (Membership roster attached.) We have been working on this problem for many months, but to no avail. Following your hearing on June 15, Mr. Newton Cattell of the Association of American Universities, Mr. David Withrow of Congressman Cooper's staff and I met with Mr. Shane and Mr. Snare of the SBA. This meeting was suggested by Mr. Wittig and Mr. Lavine, counsels for the Small Business Committee, to exploere acceptable solutions to the problems. We were not successful. Apparently the solution must come through corrective legislation.

I am bringing this to your attention because I feel it has a direct bearing on the issues your hearings were addressing. I also feel that the intent of Congress in providing for the set asides for small businesses did not visualize situations such as we now face in the R&D programs of FHWA. I would hope that you could actively support corrective legislation to bring the laws, and the regulations stemming from them, to a more rational plane.

Again, I appreciate the opportunity of appearing before your joint hearings and if I can provide additional information, please let me know.

Sincerely,

C. V. Wootan

C. V. Wootan
Director

CVW:nht

Attachments

US Department
of Transportation

**Federal Highway
Administration**

Research Development
and Technology

Turner Fairbank Highway
Research Center
6300 Georgetown Pike
McLean Virginia 22101

MAY 23 1983

In Reply Refer To:
HRT-20

Dr. C. V. Wootan
Director
Texas Transportation Institute
The Texas A&M University
College Station, Texas 77843

Dear Dr. Wootan:

This is in response to your April 8 letter in which you comment on RFP No. DTFH61-R-00088, "Real-Time Motorist Information Displays." As you know, this requirement has been determined suitable for the Department of Transportation's small business set-aside program and thus, contracting agencies not considered small businesses are ineligible proposers.

The Federal law states that "the Government should aid, counsel, assist, and protect, insofar as it is possible, the interests of small-businesses concerns in order to preserve free competitive enterprise, to ensure that a fair proportion of the total purchases and contracts...for the Government...be placed with small-business enterprises...." In supporting this law, the Federal Highway Administration has adopted the policy of considering each contract requirement for possible completion by small business firms on the basis of technical aspects of the requirement and availability of appropriate small business firms. In this way a proportion of the annual Research, Development, and Technology program can be made available to small business firms.

The Federal Highway Administration expects to place continued reliance on the established research and development agencies such as the Texas Transportation Institute (TTI) to carry out the more complex types of initial investigative research studies. We have found the past contributions of the TTI were most vital to the Nation's highway programs, and we are looking forward to continuing to work with you on other contract requirements.

Sincerely yours,

E. M. Wood
Associate Administrator

CUTC Council of University Transportation Centers

MEMBERSHIP

ILLINOIS UNIVERSITIES TRANSPORTATION RESEARCH CONSORTIUM
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
NORTHWESTERN UNIVERSITY
OREGON STATE UNIVERSITY
POLYTECHNIC INSTITUTE OF NEW YORK
TEXAS A&M UNIVERSITY
THE PENNSYLVANIA STATE UNIVERSITY
THE UNIVERSITY OF KENTUCKY
THE UNIVERSITY OF NORTH CAROLINA
THE UNIVERSITY OF TENNESSEE
THE UNIVERSITY OF TEXAS
UNIVERSITY OF CALIFORNIA
UNIVERSITY OF NORTH FLORIDA
UNIVERSITY OF PENNSYLVANIA
UNIVERSITY OF VIRGINIA
VANDERBILT UNIVERSITY

ADDRESS REPLY TO:
The University of Tennessee
713 Andy Holt Tower
Knoxville, TN 37996-0170

MEMORANDUM

DATE: April 8, 1983

FROM: Dr. K. W. Heathington

TO: CUTC Members

SUBJ: Listing of Members and Associate Members of CUTC

I am enclosing what I believe to be an accurate listing of the members and associate members of CUTC. This list also includes appropriate individuals who work with CUTC from each institution. In addition, I am enclosing a listing of the executive committee members and their terms of office.

Would you please check these listings and provide me with any inaccuracies which you find. My goal is to get our records straight this year, if at all possible. Your help will be appreciated.

KWH/th

Enclosures

April 8, 1983

COUNCIL OF UNIVERSITY TRANSPORTATION CENTERS

Elected Executive Committee Members

	Name Name	Date Elected	End of Term
*	Dr. Gordon J. Fielding	Summer 1982	Summer 1985
*	Dr. Edd Hauser	Summer 1981	Summer 1983
*	Professor Robert P. Neuschel	Summer 1980	Summer 1983
*	Dr. Louis J. Pignataro	Summer 1982	Summer 1984
**	Mr. Milton Pikarsky	Summer 1981	Summer 1983
**	Dr. Jay A. Smith, Jr.	Summer 1982	Summer 1985

Note: Officers and immediate Past President are automatically members for a given year.

Present Members

Dr. K. W. Heathington - President
Dr. Robert D. Pashek - Immediate Past President
Dr. B. Frank McCullough - Vice President
Dr. Lester A. Hoel - Secretary

* From Division of Members
** From Division of Associate Members

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University of Illinois Urbana Champaign
University of Illinois Chicago
University of Chicago
Illinois Institute of Technology

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IIT Research Institute
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VANDERBILT UNIVERSITY

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Transportation Research Group
Department of Civil and Environmental Engineering
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TREASURER OF CUTC

✓ Mr. William A. Goodwin, P.E.
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Tennessee Technological University
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Cookeville, TN 38501

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APPENDIX II

DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
WASHINGTON, D.C. 20590

OFFICE OF
THE ADMINISTRATOR

AUG 2 1983

IN REPLY REFER TO:
HRD-3

The Honorable Dan Glickman
Chairman, Subcommittee on Transportation,
Aviation and Materials
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Glickman:

As a follow up to the joint hearing with the Subcommittee on Investigations and Oversight on June 16 regarding Research and Development in the Department of Transportation, I am pleased to provide a copy of the report titled, "Plan for Utilization of Laboratories at the Turner-Fairbank Highway Research Center."

It should be noted planning for many of the major experiments began more than 2 years before the completion of the new laboratories in order to place orders for long lead time equipment purchases such as the components for the HYSIM (Highway Driving Simulator), the pumps and tilting flume for the hydraulics laboratory, and the high pressure oil systems for the servo-acuators for dynamic and repeated loadings in the structures laboratory. The delivery of the latter items will occur over the next several months as the building contractor finishes the installation of heavy duty electrical circuits and other final completion items for the building contract.

We look forward to the continued productivity of the existing laboratories and to the early initiation of major experimental programs in the new facilities as indicated in the summary report.

A similar letter is being sent to Representative Albert Gore, Jr.

Sincerely yours,

L. P. Lamm
Deputy Administrator

Enclosure

PLAN FOR
UTILIZATION OF LABORATORIES
1983 - 1986

TURNER-FAIRBANK HIGHWAY RESEARCH CENTER
MCLEAN, VIRGINIA

FEDERAL HIGHWAY ADMINISTRATION
OFFICES OF RESEARCH, DEVELOPMENT, AND TECHNOLOGY

JULY 1983

Plan for Utilization of Laboratories
at the
Turner-Fairbank Highway Research Center

INTRODUCTION

The recent completion of the new Turner Building and the designation of the facility as the Turner-Fairbank Highway Research Center marks an important milestone in the evolution of research and development capabilities for the Federal Highway Administration (FHWA). The co-location of all elements of the Offices of Research, Development, and Technology, begun in the middle 1960's, is now virtually complete. Also, for the first time all of the technical divisions of the Offices now have a reasonably adequate level of laboratory space and equipment.

Planning for the programs to be conducted in these laboratories began even before the planning of the present expansion in the mid-1970's. The requirements of the program dictated the components to be included in the expanded facilities and the resolution of conflicting requirements when it was necessary to build to a fixed budget. Before discussion of the detailed plans for the utilization of specific laboratories, it is appropriate to explain the philosophy of the FHWA with respect to in-house research as contrasted with contract research activities and Federal-aid support of research in the State highway agencies or their contract programs.

The Federally Coordinated Program of Research and Development in highway technology is the management expression of our understanding of our responsibility to coordinate our staff and contract efforts with those of the State highway agencies to ensure that resources will be focused on critical problems and there will be a minimum duplication of effort. Because of this responsibility, the project managers of our staff act in a dual capacity of project leaders and participants. A project manager's primary responsibility is to promote coordinated efforts between our contract program and the Federal-aid research activities of the States. At the same time, we believe it is essential they be a participant in the actual conduct of research studies related to their particular assignment.

This participation in the actual conduct of research studies constitutes our in-house (staff) program. In spite of the fact it currently consists of only 5 or 6 percent of the total program by funding, we are convinced it is of great importance and makes a major contribution to the success of the total program. First of all, by this means our technical specialists maintain a high level of technical competency, providing them with an important asset in leadership of their areas of the program. Nothing works quite so well in obtaining the cooperation of the State highway agencies and others as when they respect the competency of the project manager. Second, it provides a broad range of specialized capabilities which can be tapped on short notice by the operating offices of the FHWA for special investigations and quick studies to resolve immediate problems which arise in the field. This technical assistance to the operating offices is well established and presently consumes on the order of 10 to 15 percent of the time of our staff. Third, the maintenance of opportunities for participation in research by our staff is an important element in our ability to attract and maintain a competent staff of specialists, since it provides both professional recognition and opportunities for growth.

The new laboratories will greatly enhance the scope and quality of the in-house program. By a combination of further efficiencies in management and the use of support contractors, it is hoped to expand the in-house program from 5 percent to between 10 and 15 percent of total program funding. As availability of staff permits, we would like eventually to raise staff participation from its present 20 percent of professional person-hours to between 40 and 50 percent of professional person-hours, excluding management personnel at the Division Chief level and above. It is not intended that we make any attempt to move from a predominantly contract and Federal-aid program to a predominantly in-house activity. The expertise in highway related technology is distributed throughout the country in the many laboratories of the State highway agencies, in private consultants, not for profit research centers, and universities. We intend to continue to involve this pool of talent in the program, but hope to expand and enhance the opportunities for our staff to develop more effective leadership and greater ability to achieve effective results from our investments in contract research. To ensure this will happen, the selection of studies which will be conducted in-house must be very carefully made. Emphasis will be upon developing fundamental insights into our chronic highway problems, special investigations and quick turnaround solutions for specific emergency problems, and the development of staff capabilities.

RELATIONSHIP TO PROGRAM

The Federally Coordinated Program contains five major categories of problem related activity as follows:

(1) Safety

(2) Traffic Operations

(3) Environmental and Maintenance Management

(4) Pavement Technology, and

(5) Structures and Hydraulics

For each of these areas an appropriate segment of total activity has been selected for the in-house program in support of the overall program goals. The selection of these areas exerted a strong influence on the allotment of resources for constructing the major new laboratories, as follows:

1. Highway Safety

The goals of the highway safety program include providing effective guidelines for the design and marking and delineation of highway systems; development and placement of appropriate hazard warning signs and traffic control devices; correction of safety related surface and geometric problems for all classes of vehicles, including trucks; provision of roadside hardware to mitigate the consequences of accidents involving run-off-the-road events; and the development of systems to deal with visibility in adverse weather and darkness, and improved speed control. A study of the existing facilities available in the country for addressing these problems led to the following selection of unique and specialized facilities for the in-house laboratories.

It should be noted that some of the following facilities may also provide significant support to more than one major category. For example, the human factors research facilities are used in both safety and traffic operations research and development.

(a) The Highway Simulator (HYSIM) is a state of the art, fully interactive highway driving simulator system for study of driver performance. HYSIM is flexible in design with capabilities to meet near term research needs and, through anticipated enhancements, to respond to future research needs. The system will be used to (1) evaluate driver's reactions to new or modified highway signs, signals, auditory messages, markings or other traffic control devices; (2) measure driver performance in various roadway situations and environmental conditions; and (3) compare the relative effectiveness of traffic control systems under development.

HYSIM advantages, compared to subject testing in operational highway situations, include capability to conduct driver performance research (1) under safe conditions, (2) under highly controlled conditions, and (3) at less cost than comparable field studies. It is particularly useful in preliminary screening of large numbers of candidate traffic control devices and for subsequent identification of those devices with the greatest potential for further field evaluation.

(b) A specialized crash impact testing facility (FOIL, Federal Outdoor Impact Laboratory) which will permit the physical test evaluation of new concepts for guardrail, bridgerail, and breakaway hardware at low expense through utilization of a "logic vehicle" which simulates the crush characteristics of a variety of real vehicles.

(c) A Human Factors Laboratory complex will permit investigations of driver performance in various highway situations and preliminary exploration of possible changes in signing, marking, lighting, and geometrics to correct such problems. In many cases, the output of the work of this facility will provide the most promising concepts for further examination by experiments in HYSIM or with instrumented vehicles on the actual highway system.

(d) Additional scientific equipment for existing laboratories dealing with the physical aspects of highway surfaces from a skid resistance or roadway profile standpoint, and supporting work on highway safety questions which involve materials or structures.

(e) Supporting facilities for development, calibration and maintenance of instrumented vehicles and other equipment used in field studies of safety problems (see Highway Electronics Laboratory and Field Equipment Development Laboratory).

2. Traffic

The primary goals of this category in the program are to reduce traffic congestion by improvement of traffic flow and to encourage more efficient utilization of existing facilities by coordination of passenger automobile traffic with other components in the traffic stream and mass transit facilities. The emphasis in the program has been on the utilization of modern computer technology to achieve more effective control of traffic signal systems, and on information systems to provide real time advisories to motorists to help them become effective participants in the improvement of traffic flow. The laboratory facilities to be used in this program overlap to a major degree those which are useful in resolving safety problems such as the driving simulators (HYSIM), the Human Factors Laboratory, and the Field Equipment Development Laboratory. In addition, this program element provices much of the activities in two major support facilities:

(a) Highway Electronics Laboratory -- This laboratory permits our staff to be involved in direct exploration of methods to exploit modern electronics technology in traffic operations and highway information systems. This facility has three roles which pertain not only to the traffic program element but to other activities in the total program as well, namely, (1) electronic support to Research, Development, and Technology and other elements of FHWA, (2) development of prototype traffic control devices, often in conjunction with the private sector and (3) the design, fabrication, and maintenance of specialized instrumentation systems for use by other staff elements, such as unique data acquisition systems.

(b) Central Computer Facility -- This is currently a contractor operated support service to all elements of the program. It is used rather heavily by the traffic oriented elements for such purposes as simulation of traffic flow problems on freeways, urban street networks and rural two-lane highway facilities, development of algorithms for traffic signal control, and statistical studies of traffic and safety problems.

3. Environmental and Maintenance Management

This particular program activity presented especially difficult problems in deciding what portion of our effort in these areas should be done in-house. This results from the fact that the environmental program is past its peak level of activity and is in the process of phasing out as we resolve the problems in air pollution, noise, and water supply pollution as it relates to highway design and operation. On the other hand our investment in maintenance related activities is increasing, but it has already become apparent that most of the laboratory facilities for investigating maintenance related issues parallel those required for the development of pavement technology, traffic control devices, corrosion protection and the extension of life expectancy for bridges. It is anticipated, therefore, that except for a laboratory provided for our current programs in noise mitigation, the other functions of this category can be supported with existing laboratories or the new facilities being provided for other program elements.

4. Pavement Technology

The construction, rehabilitation or maintenance of pavements still continues to be a part of the annual highway investment. Since the design of an effective reconstructed pavement parallels in many respects the design of new pavements a continued effort to produce more reliable methodology for pavement design and construction is required. The existing laboratories have provided extensive facilities for the investigation of pavement materials, but limited experimental facilities for examination of the structural performance of complete pavement systems. In planning the new facilities we have provided some extension of these capabilities with:

(a) Pavement Performance Laboratory -- This facility will provide for experiments on full scale pavement sections and components using static and dynamic loadings, but will be restricted to fixed position loads. This is primarily a relocation of existing capabilities which shared very cramped quarters in the old Structures Laboratory.

(b) Modernization of the Pavement Mixtures Laboratory and the Pavement Binders Laboratory. These laboratories will have an essential role to play in the development of substitutes for petroleum derived pavement binders such as asphalt. In addition, they will continue to provide an important special investigation capability for problems that are now arising in pavement construction due to the changing composition of asphalts.

(c) Chemistry Laboratory complex. These facilities provide general support to study of fundamental problems in pavement materials technology as well as other program areas requiring this specialized capability. This facility has been obtained by upgrading an existing laboratory complex and adding modern scientific equipment to extend the range of problems which can be handled, such as high pressure chromatography and an enhanced electronic microscopic and microprobe facility.

(d) Concrete Technology Laboratories -- Concrete is one of the few construction materials which is still sometimes manufactured in the field at the construction site. Quality control problems become especially difficult because of the wide range of natural materials which must be combined with the manufactured cement to produce concrete in a wide variety of ambient conditions. The emphasis in the continuing program will be on methods to obtain even more effective quality control for conventional strength concretes and to extend the technologies so as to produce reliable concretes in the strength range from 6,000 psi to 12,000 psi for use in pavements and bridges.

One of the facilities believed to be essential to an adequate pavement technology capability has not yet been constructed. This is the APTS (Accelerated Pavement Testing System) designed to permit the application of loadings corresponded to the full range of heavy axle vehicles under controlled environmental conditions so as to achieve the following purposes:

(1) Confirmation or correction of present "damage factors" relating the development of various types of pavement distress to the number of passages of axle loadings of various magnitudes,

(2) Obtain fundamental insights into the behavior of commonly used or new methods for rehabilitation of both asphaltic concrete and portland cement concrete pavements,

(3) Experiments to improve the effectiveness of pavement repair methods including pothole correction, crack restoration, and joint repairs,

(4) Experiments to extend the present knowledge of the mechanisms of pavement failure, confirming or correcting existing

fundamental work so that it can be used in making reliable predictions of performance of pavements under a variety of loading in environmental conditions, even when they are constructed of new materials for which there is limited field experience.

5. Structures and Hydraulics

In addition to the normal problems of analysis and design of bridges in which FHWA has long played a key role, in recent years we have been confronting two additional problems (1) the quantification of the growth of small micro flaws into cracks of critical size in steel structures due to both increased numbers of heavy vehicle loadings and environmental attack, and (2) methodology for reliable assessment of the remaining life expectancy of bridges and economical means to extend life and available load capacity. The latter problem is in many ways more difficult than design of new structures and requires investigation of fundamental questions which could formerly be ignored. The problems of hydraulic design of bridges and drainage structures also confronts new challenges due to substantial changes in stream hydrology produced by intense development of formerly rural areas. The existing and recently added laboratory elements related to these problem areas have been developed to provide unique capabilities for staff participation, as follows:

(a) Structural Laboratory, which provides a heavy test floor 160' X 55' for the static and dynamic loadings of large scale bridge models or full scale bridge components. The servo-hydraulic loading equipment also permits application of repeated loads, and the facility is designed for later modification to permit such tests under controlled aggressive environments. A control room and data acquisition center serves this facility, but also provides for automated data reduction of results stored in field equipment systems, such as the Weighing in Motion (WIM) equipment, and may be connected to minor laboratories as needed.

(b) Old structures laboratory, which will now be used primarily for smaller model and component tests, and investigation of earthquake hazards to highway structures.

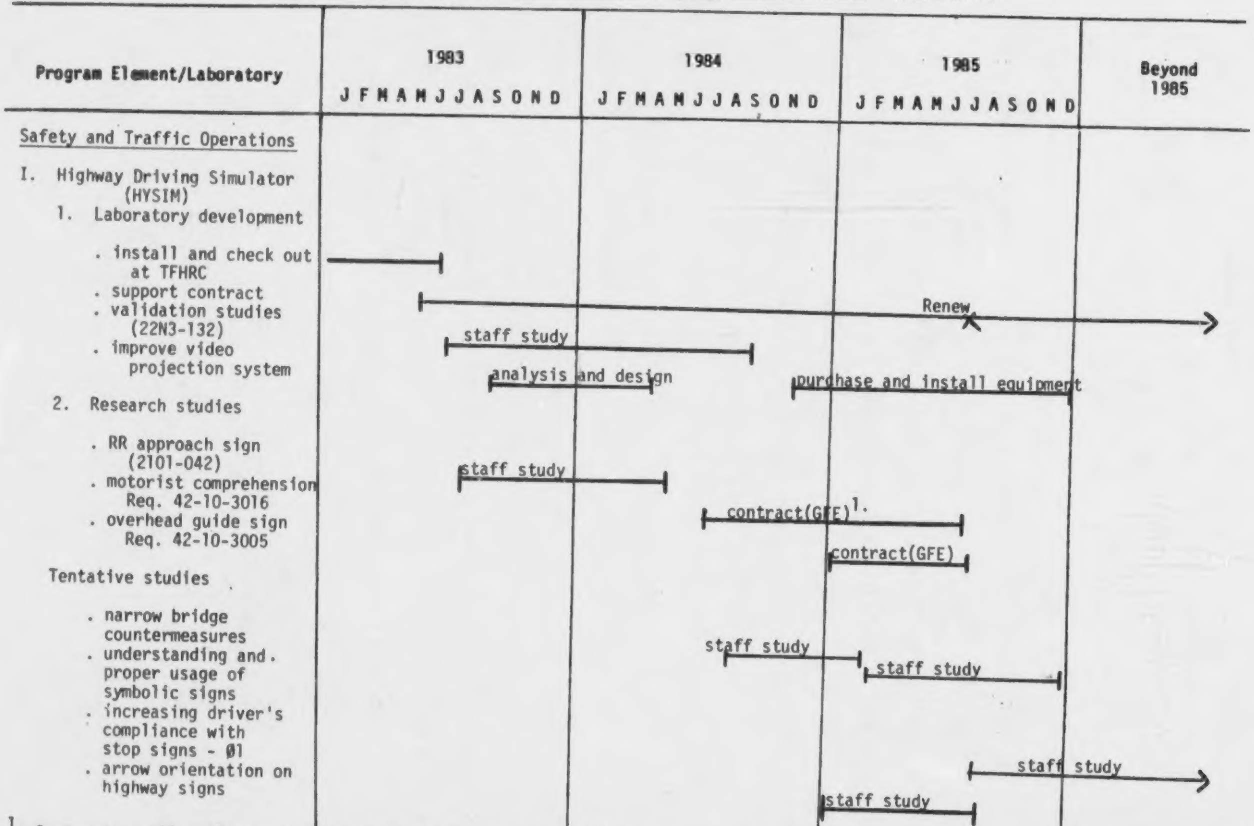
(c) Fracture Mechanics and Metallurgy Laboratories, which support the work on crack initiation and growth and on development of inspection equipment for detection of flaws in fabrication or in existing structures.

(d) Aerodynamics Laboratory, which provides a small wind tunnel now being equipped to perform studies of wind induced oscillations in bridges under turbulent conditions.

(e) Hydraulics Laboratory, which will contain both fixed and tilting flumes with large flow capacity for the resolution of problems on large culverts and studies of stream bed stability in the vicinity of bridge piers.

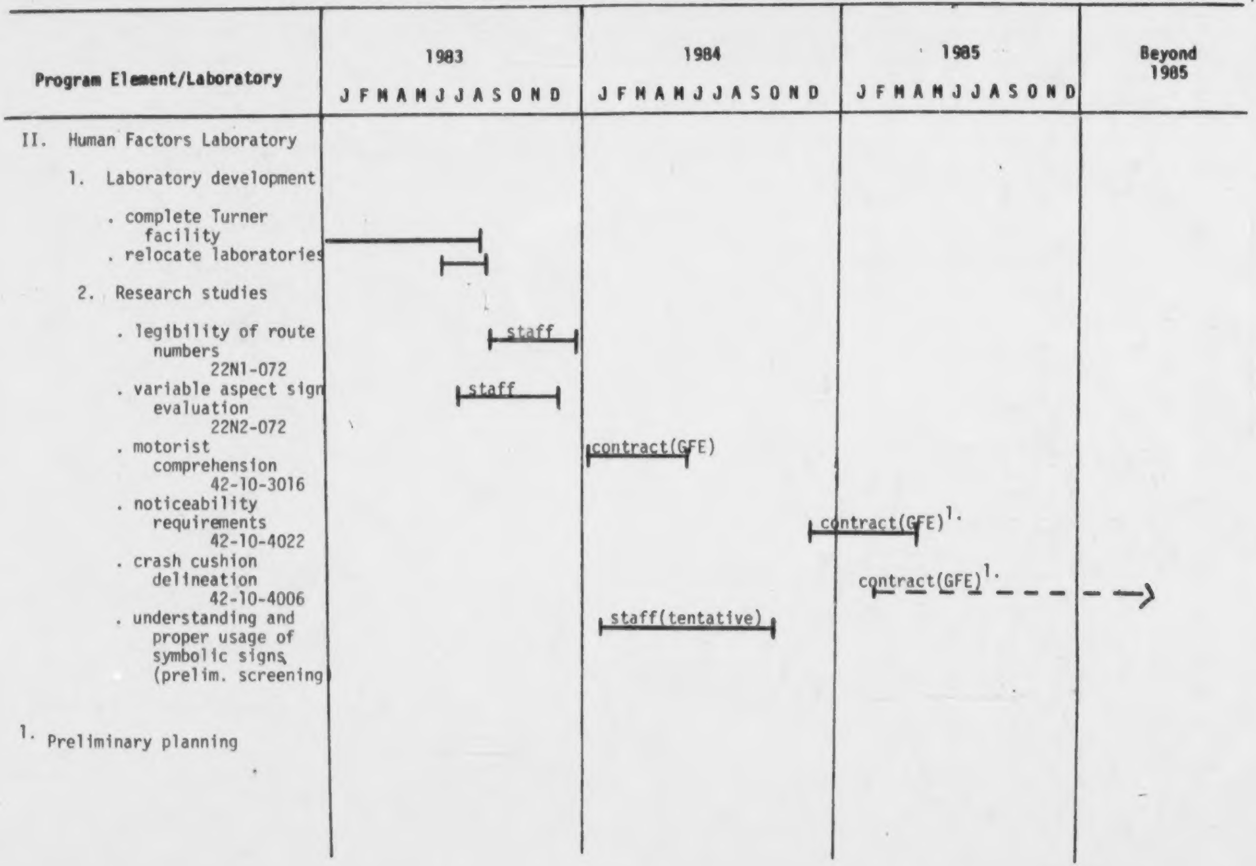
TIME-PHASE CHARTS FOR LABORATORY PLAN

Plan for Utilization of Turner-Fairbank Highway Research Center Laboratories



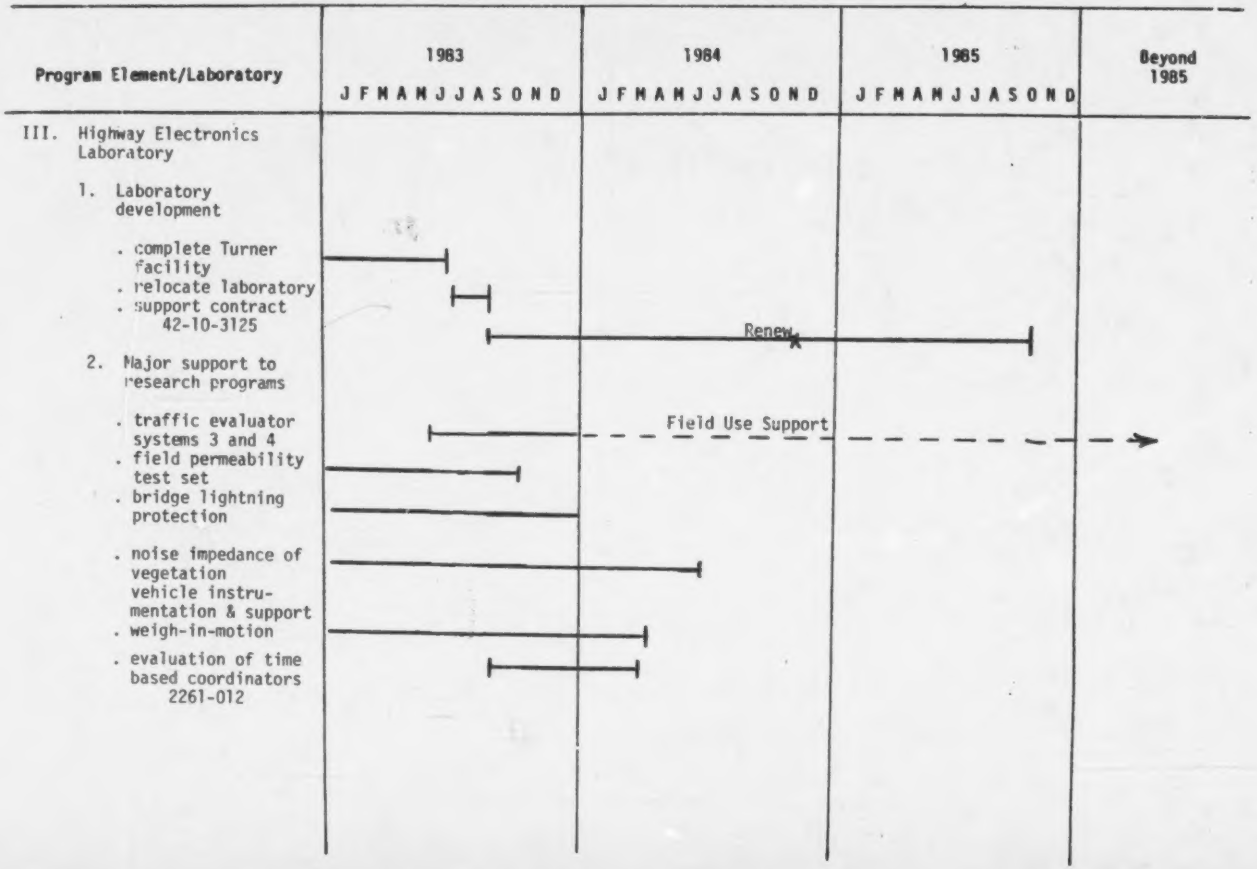
[1] Contractor will utilize the facility as Government Furnished Equipment (GFE)

Plan for Utilization of Turner-Fairbank Highway Research Center Laboratories

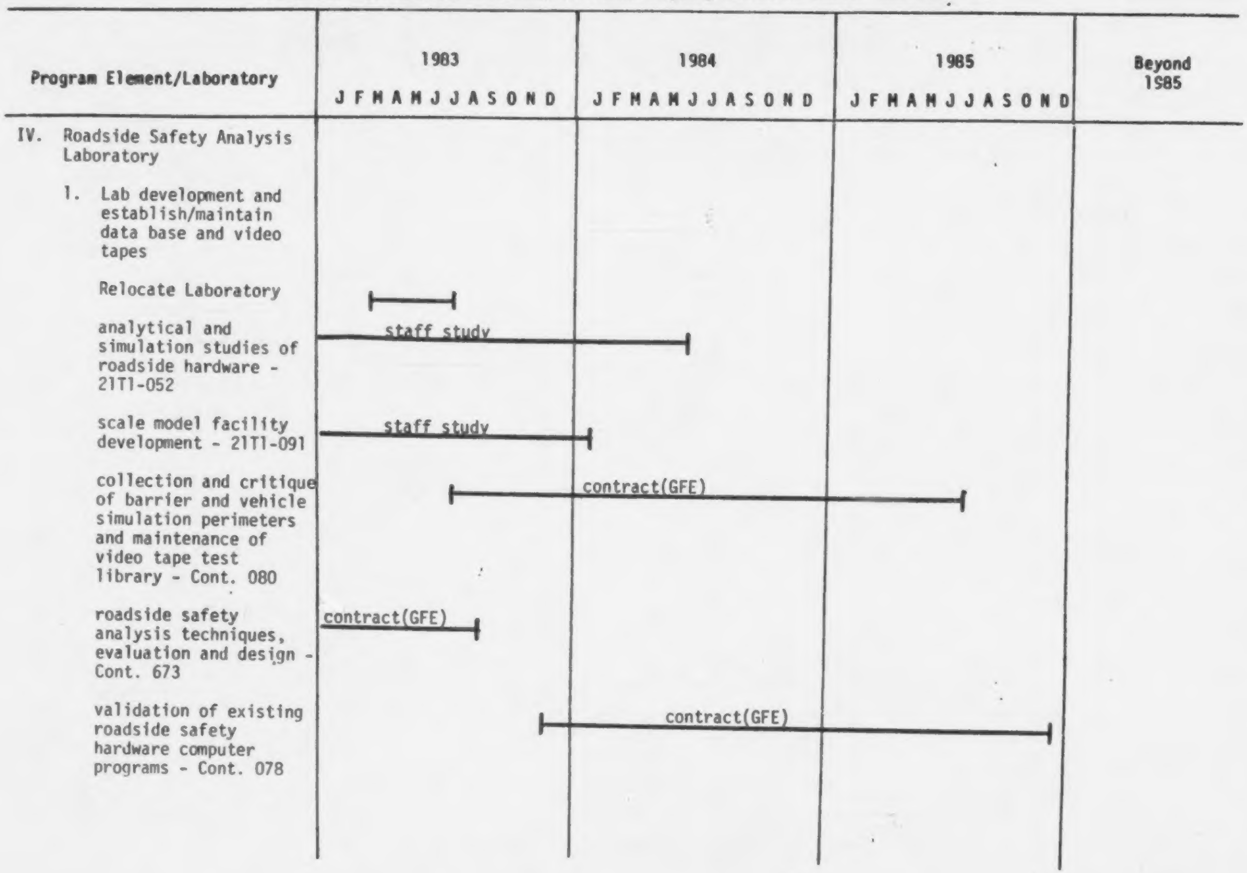


[1] Preliminary planning

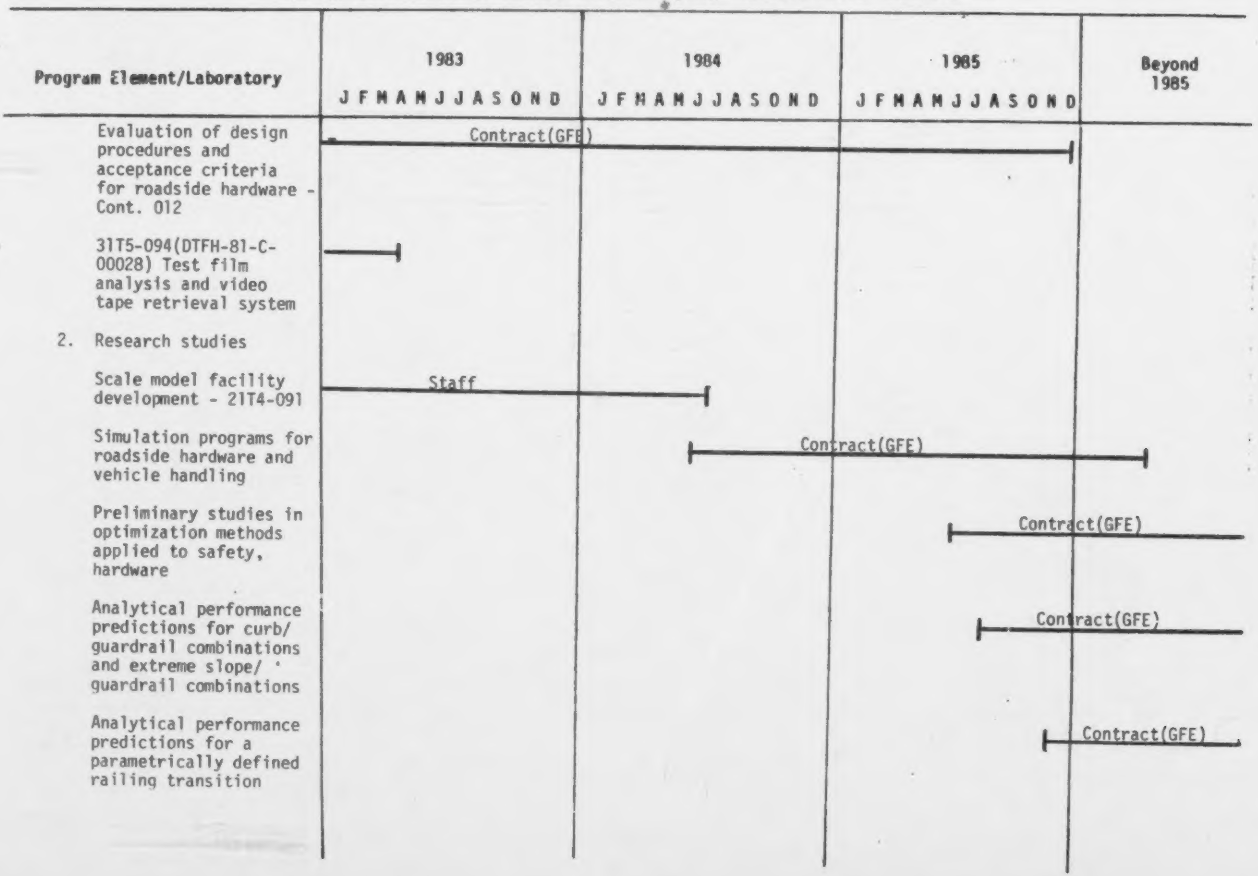
Plan for Utilization of Turner-Fairbank Highway Research Center Laboratories



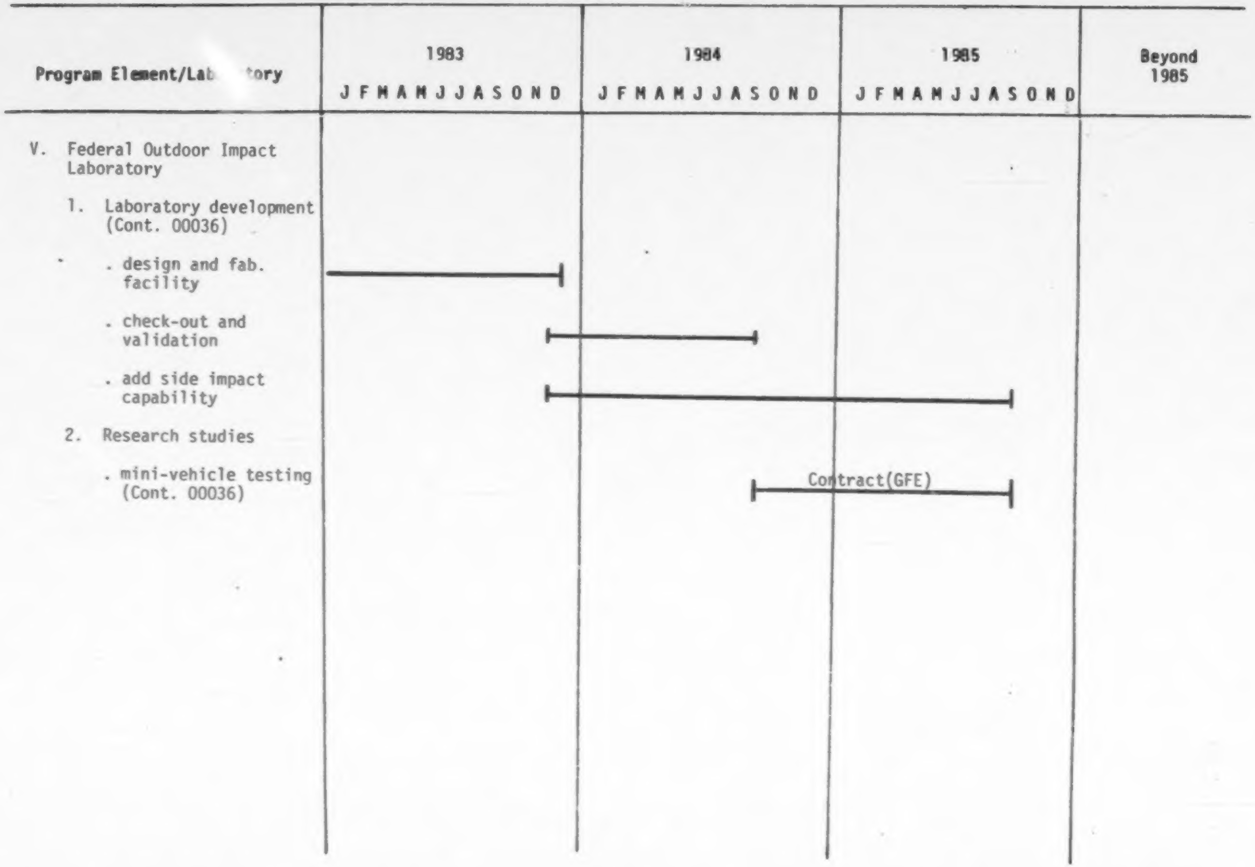
Plan for Utilization of Turner-Fairbank Highway Research Center Laboratories



Plan for Utilization of Turner-Fairbank Highway Research Center Laboratories



Plan for Utilization of Turner-Fairbank Highway Research Center Laboratories



Plan for Utilization of Turner-Fairbank Highway Research Center Laboratories

Program Element/Laboratory	1983 J F M A M J J A S O N D	1984 J F M A M J J A S O N D	1985 J F M A M J J A S O N D	Beyond 1985
Structures Laboratory *				
Laboratory development	Construction Testing System Installation	Checkout		
Initial Studies:				
An Innovative Highway Bridge Staff Study 25K3-022 Contract 35K3-172 (Autostress Design of Bridge and Deck Elements)		Test Bridge Setup	Testing Analysis & reporting	
Bridge Deck Corrosion Study 25L3-122		Experiment design Test setup	Fatigue testing	Test to failure Analysis & report

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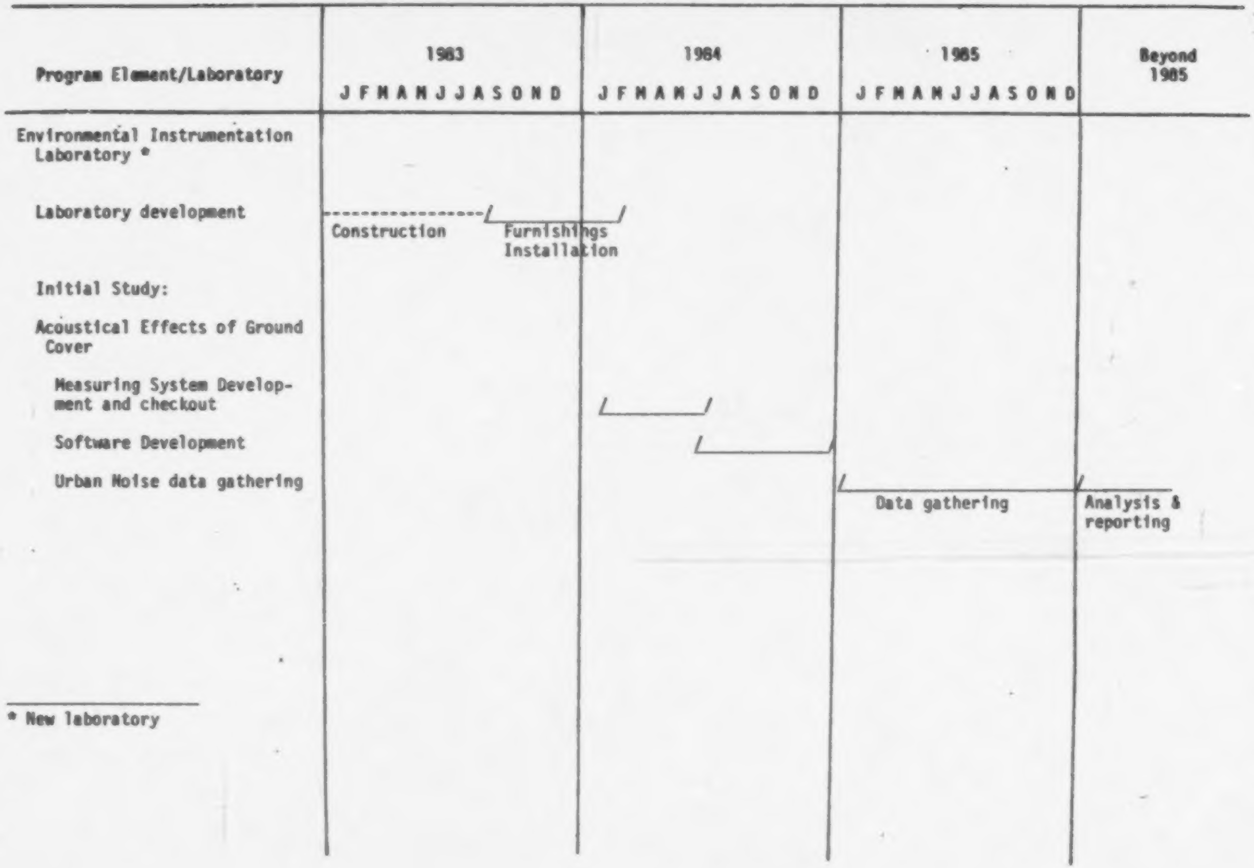
* New laboratory

Plan for Utilization of Turner-Fairbank Highway Research Center Laboratories



* New laboratory

Plan for Utilization of Turner-Fairbank Highway Research Center Laboratories

Program Element/Laboratory	1983 J F M A M J J A S O N D	1984 J F M A M J J A S O N D	1985 J F M A M J J A S O N D	Beyond 1985
Foundation Laboratory				
Continuing Studies:				
Scale Effects of Piles and Pile Groups				
Tests in sand	Test timber piles 1/15 and 1/30 scale	Analysis Test in outdoor pit, 1/3 scale		Analysis & reporting
Tests in clay		Test steel piles in clay, 1/3 scale	Pile group tests	Analysis & reporting

Plan for Utilization of Turner-Fairbank Highway Research Center Laboratories

Program Element/Laboratory	1983 J F M A M J J A S O N D	1984 J F M A M J J A S O N D	1985 J F M A M J J A S O N D	Beyond 1985
Aerodynamics Laboratory				
Deer Isle Suspension Bridge Study 25A2-052	Testing in Laminar Flow	Installation and checkout of turbulence generator	Testing in turbulence Analysis & reporting	
Evaluation of Designs in Turbulence Flow (Future staff study)			Model Testing	Analysis and Design Guides

Plan for Utilization of Turner-Fairbank Highway Research Center Laboratories

Program Element/Laboratory	1983 J F M A M J J A S O N D	1984 J F M A M J J A S O N D	1985 J F M A M J J A S O N D	Beyond 1985
Hydraulics Laboratory *				
Laboratory development	Construct and install tilting flume	Install and check instruments		
Initial studies:				
Culvert Behavior Studies 25H3-012				
Long span culverts		Tests	Analysis Reporting	
Boxes and arches			Tests Analysis Reporting	Reporting
Plastic pipe			Tests Analysis/reporting	Analysis/reporting

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* New laboratory

Plan for Utilization of Turner-Fairbank Highway Research Center Laboratories

Program Element/Laboratory	1983 J F M A M J J A S O N D	1984 J F M A M J J A S O N D	1985 J F M A M J J A S O N D	Beyond 1985
Pavement Performance Laboratory*				
Laboratory development	Construction Furnishings & electrical	Equipment checkout		
Initial Studies:				
Fatigue Tests of Flexible Pavement Components				
Specimen design and preparation		Specimen preparation	Testing Analysis & reporting	
Fatigue testing in various environments				

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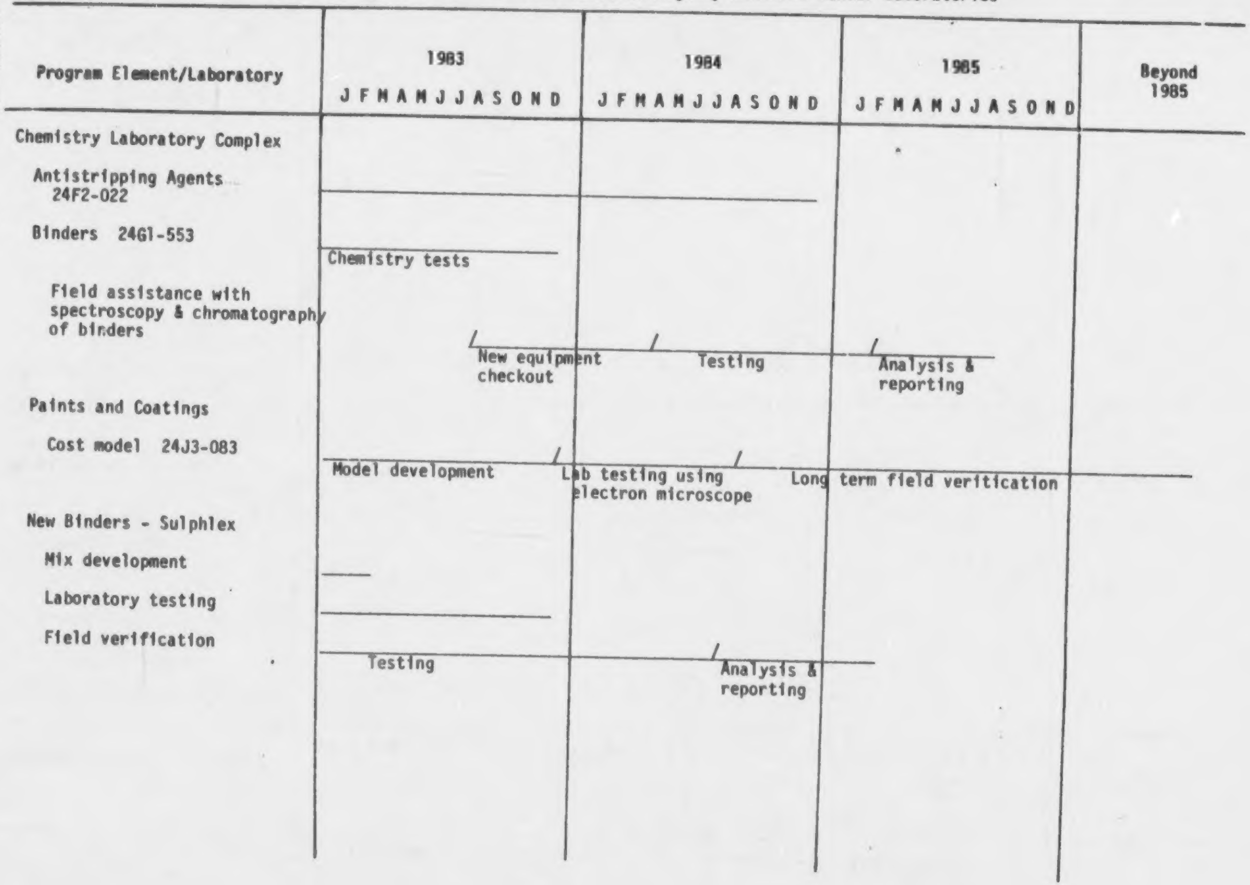
* New laboratory

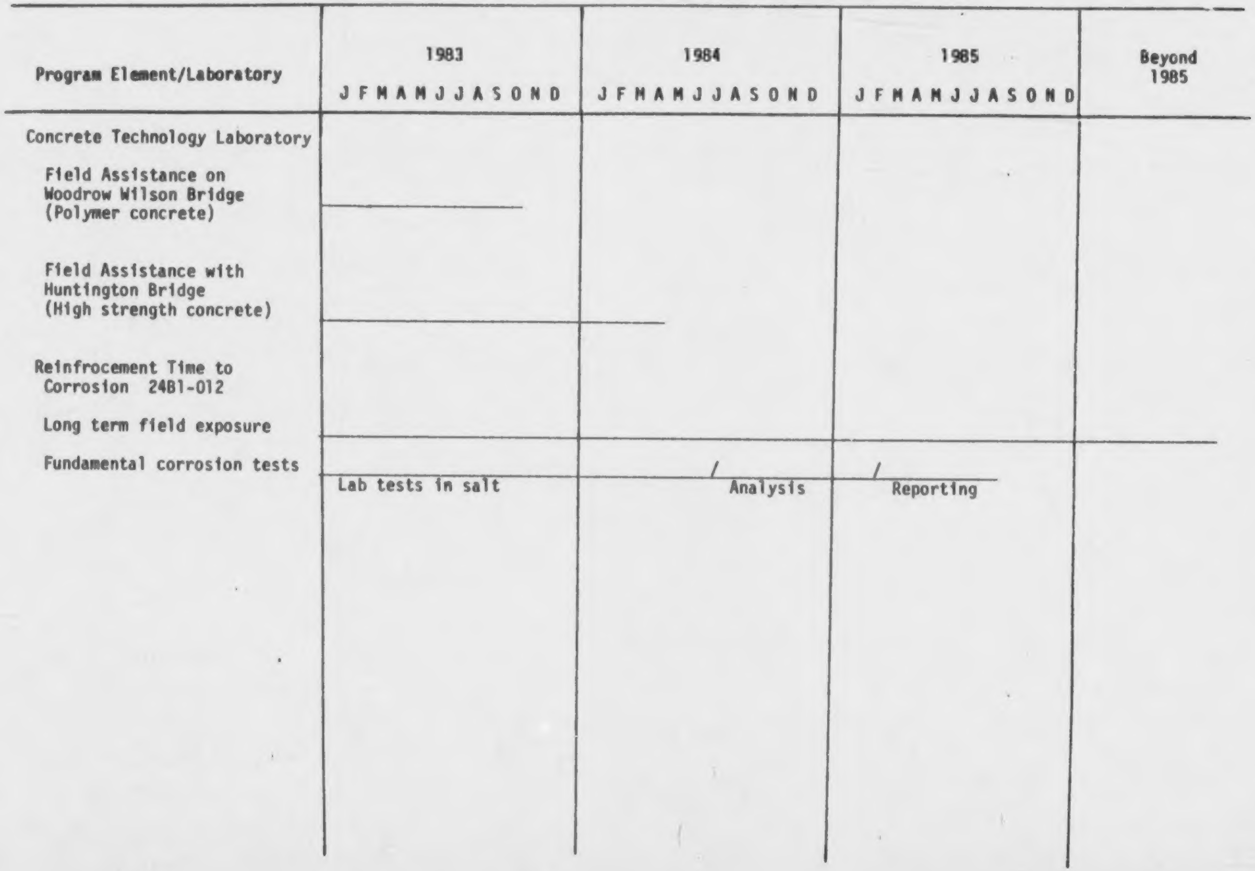
Plan for Utilization of Turner-Fairbank Highway Research Center Laboratories

Program Element/Laboratory	1983 J F M A M J J A S O N D	1984 J F M A M J J A S O N D	1985 J F M A M J J A S O N D	Beyond 1985
Bituminous Mixtures Laboratory				
Stripping of Asphalt Pavements	Tests	Analysis	Reporting	
Pavement Surface Evaluation				
Aggregate slipperiness	Testing	Reporting		
Microtexture test development	Equipment design Lab testing	Field testing	Analysis	Reporting
Macrotexture tests	Small specimen tests	Field testing	Analysis	Reporting

Plan for Utilization of Turner-Fairbank Highway Research Center Laboratories



Plan for Utilization of Turner-Fairbank Highway Research Center Laboratories



PLANS FOR SPECIFIC LABORATORIES

6/27/83

Highway Simulator Laboratory (HYSIM)

The Highway Simulator (HYSIM) is a state-of-the-art, fully interactive highway driving simulator system for study of driver performance. HYSIM is flexible in design with capabilities to meet near term research needs and, through anticipated enhancements, to respond to future research needs. The system can (1) evaluate driver's reactions to new or modified highway signs, signals, markings or other traffic control devices; (2) measure driver performance in various roadway situations and environmental conditions; and (3) compare the relative effectiveness of developmental traffic control systems.

HYSIM advantages, compared to subject tesing in operational highway situations, include capability to conduct driver performance research (1) in safety, (2) under highly controlled conditions, and (3) at less cost than comparable field studies. It is particularly useful in preliminary screening of large numbers of candidate traffic control devices and for subsequent identification of those devices with the greatest potential for further field evaluation.

The HYSIM facility provides services to FHWA staff researchers, non-government contractors performing research under FHWA administrative contracts, and, in selected areas, university researchers working within FHWA/university research agreements. Operational support for HYSIM is provided under contract DTFH61-83-00019 with ENSCO, Inc., Springfield, Va.

The HYSIM is a new acquisition and is currently undergoing final testing and "debugging" at the Turner Fairbank Highway Research Center (TFHRC). The initial study scheduled (22N3-132) consists of a series of experiments to validate measures obtained from the HYSIM against data collected in the "real world." This study is scheduled to begin in July 1983 and is essentially to insure HYSIM data are representative of driver responses obtained under actual driving conditions.

One of the first major research uses of HYSIM will be as part of an FHWA contract to evaluate the effectiveness of roadway signs identified as "misunderstood or misinterpreted" by drivers. Subsequently, an evaluation of new or modified signs designed to replace inadequate signs will be undertaken. This work will be conducted as a part of the contract resulting from RFP No. DTFH61-83-R-00118.

A staff study (2101-042) scheduled to begin in September 1983, will evaluate drivers' reactions to (1) a modified cross buck railroad grade crossing sign (addition of a 2" wide black border), and (2) the standard pavement marking symbol - a large X with an R on each side - versus a modified symbol with the R's removed. The purpose of the cross buck border is to increase safety by enhancing driver's awareness of the signal. Regarding the pavement marking, if adequate driver response can be maintained without inclusion of the R's, savings in application of the symbol can be realized.

Studies to evaluate traffic devices will continue for the foreseeable future. For example, there are two signing studies already scheduled for HYSIM within the next three years. One contract study (RFP DTFH61-83-R-00184) is concerned with a determination of the detection and legibility requirements of overhead guide signs with recommendations concerning selected use of illuminated, non-illuminated and reflective sign treatments. The HYSIM will be used in several aspects of this research.

In terms of less well defined areas where HYSIM may be utilized within the next several years as research priorities and emphasis change, it is anticipated the simulator will also be utilized to address problems in driver performance degradation attributable to affects of driver aging, driver fatigue, and adverse environmental factors.

Human Factors Laboratory

The Human Factors Laboratory consists of essentially three rooms and associated specialized equipment which are used in the conduct of research related to driver performance. The primary room consists of a photographic projection room where visual stimulus materials are presented to test subjects in studies of signs, signals and markings. The other two rooms are used as support areas to conduct subject briefings, administer vision tests, prepare stimulus materials, setup apparatus, and reduce and analyse data. The Human Factors Laboratory also includes a specially instrumented automobile for performing controlled field tests under actual highway conditions.

The facilities are used both by FHWA staff in the conduct of inhouse research and by contractor´s as GFE in some selected research studies.

One of the initial experiments in the new Human Factors Laboratory will involve tests of the legibility of route numbers on overhead guide signs (FCP No. 22N1-0721). A staff study will determine the effect on legibility of numeral size, number-shield spacing, number style, and shield coloration. Recommendations will be developed for route shield design elements to improve route number legibility. A second staff study is concerned with the conspicuity of a new type of sign called a variable aspect sign (FCP No. 22N2-072). Driver eye-movements in the vicinity of the variable aspect sign will be compared to those near standard warning signs. Recommendations will be made for using the variable aspect sign for highway applications.

Two studies are anticipated to use the Human Factors Laboratory as GFE to FHWA contracts. One study is concerned with the illumination and reflectorization of overhead guide signs (RFP No. DTFH61-83-R-00184). In this study recommendations will be made concerning selective use of illuminated, non-illuminated, and retroreflective overhead sign treatments. In another contract effort, regulatory, warning and symbol signs which exhibit motorist comprehension problems will be examined in the Human Factors Laboratory and in simulator and field tests (RFP No. DTFH61-83-R-00118).

Future studies in the Human Factors Laboratory are generally oriented towards developing improved traffic control devices and guidance systems which are compatible with driver characteristics. For example, studies on the Noticeability Requirements for Delineation of Non-Illuminated Highways (PR No. 42-10-4022) and the Development of Improved Crash Cushion Delineation (PR No. 42-10-4006) will be conducted during the 1985-1987 period.

FOIL

The Federal Outdoor Impact Laboratory (FOIL) is a facility for frontal and side impact testing of luminaires, signs, and poles.

FHWA's pendulum test facility at Riverdale, Maryland, has demonstrated that laboratory tests are much less expensive than full-scale tests, with automobiles. Under Contract DOT-FH-11-9194, "Laboratory Evaluation of Existing Breakaway Structures," Ensco, Inc., tested a whole array of existing luminaire supports and developed improved supports using a soft-nosed pendulum device. A rugged, reuseable "logic vehicle" test device was also built and validated for use in testing dual-legged breakaway sign supports. The pendulum device was recently used by Ensco, Inc., under Contract DOT-FH-11-9614, "Safety Modifications of Turned-Down Guardrail Terminals," to test breakaway wooden posts for a new guardrail terminal. Ensco, Inc., is currently using the pendulum device to test luminaire supports on sideslopes under Contract DTFH61-81-C-00036. Although the pendulum and the logic vehicle are extremely useful test devices, they are limited to modeling 20-mph impacts at the frontal centerline of only one vehicle, a 1973 Chevrolet Vega sedan.

The FOIL test facility is currently being constructed at the Turner-Fairbank Highway Research Center by Ensco, Inc., under Contract DTFH61-81-C-00036, "Laboratory Procedures to Determine the Breakaway Behavior of Luminaire Supports in Mini-Sized Vehicle Collisions." The new logic-vehicle test device is being designed so that it can have the same frontal crush characteristics, inertia properties, etc. as a variety of automobiles in the 1,400-lb to 2,800-lb weight range. It can be used for centerline and off-center testing at speeds ranging from 20 to 60 mph. Full-scale tests have shown that 1,800-lb mini-compact cars can overturn after impacting luminaire supports off-center at 60 mph. This problem will be studied in detail after the logic test device has been validated against the full-scale test data. The facility is programmed to be completed in the spring of 1985.

The FOIL test facility will also give FHWA the capability of conducting side-impact tests with automobiles into breakaway poles and luminaires in ordcer to study their behavior and to develop improved design guidelines. In the future, a logic vehicle will be developed to model side impacts.

ROADSIDE SAFETY ANALYSIS LABORATORY

The Roadside Safety Analysis Laboratory (RSAL) was created to act as a central clearinghouse for all analysis, design, and testing information related to highway safety appurtenances. The information present in the laboratory includes a library of computer simulation programs for modeling vehicle impacts with roadside structures, full-scale impact test data and films.

The library contains a user-friendly, information retrieval system which allows researchers to locate existing experimental data for use in a variety of available computer analysis models. The information in the library will be used to identify and design improved roadside hardware. The library will make the solution and search process more efficient and provide a greater potential for success, thus, avoiding expensive interactive redesign and full-scale crash test phases.

As a long-term goal, the uses of the library will be extended to State highway departments.

The following staff studies and contracts are involved in this facility:

1. Staff Study, FCP 21T1-052, "Analytical and Simulation Studies of Roadside Hardware."
2. Contract, FCP 31T1-034 (RFP 83-R-00080), "Collection and Critique of Barrier and Vehicle Simulation Parameters and Maintenance of Video-Tape Test Library."
3. Contract, FCP 31T4-014 (FH-11-9673), "Roadside Safety Analysis Techniques, Evaluation, and Synthesis."
4. Contract, FCP 31T4-084, (DTFH61-83-C-00008), "Validation of Existing Roadside Safety Hardware Computer Programs."
5. Contract, FCP 31T5-032 (DTFH61-82-C-00112), "Evaluation of Design Procedures and Acceptance Criteria for Roadside Hardware."
6. Contract, FCP 31T5-094 (DTFH61-81-C-00028), "Test Film Analysis and Video-Tape Retrieval Library."

Highway Electronics Laboratory

The Highway Electronics Laboratory supports the electronic technology program needs of the Offices of RD&T and other elements of FHWA. It also is utilized by staff in the performance of in-house R&D studies involving electronics technology. The laboratory is equipped with a complete range of scientific instruments to generate, measure, control, analyze and record signals from DC through 10 GHz. Technical and operational management of the laboratory is performed by FHWA staff; however, on-site technical staffing is primarily via an electronic support services contract. Off-site vendors or contractors provide electronic parts, materials, fabrication and assembly services to assist the laboratory in supporting the design, fabrication and repair of scientific instrumentation systems.

In its role as an electronics support facility to RD&T, the laboratory and staff performs a full range of activities including: providing technical consultation; troubleshooting and repairing electronic instrumentation; and designing, developing, and fabricating specialized electronics instrumentation. Typical individual jobs range from a few minutes of technical assistance to significant developments requiring up to two years of schedule time.

The laboratory is also used in the conduct of in-house staff research studies involving highway electronics. A current in-house study scheduled to be completed in FY '84 is investigating the performance and operating characteristics of time based traffic signal coordination units (FCP No. 22L1-112). There currently is no "standard" for these units and there is a need to determine the compatibility, interchangeabilty, and operating characteristics to assist States and local jurisdictions in implementing these systems. The study includes the use of a contractor to perform a series of performance tests using instrumentation available in the laboratory. Other future projects involve the design, fabrication, and installation of devices in test vehicles, instrumented bridges, and field test monitoring equipment, involving acoustics, hydraulics, environmental, optical, and mechanical stress disciplines.

To address the increasing use of microprocessors in traffic control systems, scientific instruments, and our own designs, a new microprocessor development system is being added to the laboratory capability. This will allow the staff to design new software or modify existing systems as needed. It is anticipated the long term use of this laboratory will continue to provide electronic support services to other RD&T laboratories and provide a well equipped facility for staff research projects.

STRUCTURES LABORATORY

The initial experiment in the new structures laboratory will involve the design, construction, and testing to failure of an innovative highway bridge. A large scale model (approximately 120 ft. long and 45 ft. wide) of a two span continuous steel plate girder bridge will be designed using the "autostress" principle of design, which is a method that allows for the more efficient use of steel in that it takes advantage of the relatively large reserve of strength beyond the elastic range behavior of commonly used construction steels.

In addition to using an innovative design concept for the main members, the test specimen will also use several new concepts for deck elements, such as waffle-slab prestressed concrete deck. The bridge will be subjected to both static, dynamic, and repeated loads as these new concepts must be thoroughly verified before they can be admitted into standard design practice. This study is being co-sponsored on a cost sharing basis by the American Iron and Steel Institute.

Because of the large scope of this experiment, the staff manpower effort will be supplemented by outside service contracts. It is estimated that this first experiment will be completed by July of 1985.

Future experiments in the structures laboratory will continue to explore new structural concepts, and will include studies of bridge components under adverse environments. One study now in planning stages will use primarily existing equipment to construct seismic shake tables to simulate earthquake loadings on long span suspension bridges.

Reference: Staff study No. 25K3-022, An Innovative Highway Bridge.
Contract: No. 41-11-2699, Structural Modeling for Autostress by Loading Through Various Deck Systems.

HYDRAULICS LABORATORY

The initial experiment in the new hydraulics laboratory will involve tests on long span and special shape culverts. Long span culverts are frequently used instead of short bridges, often with material cost savings as well as construction time savings. Presently there are no experimentally based design guidelines for entrance loss coefficients for these types of culverts and it is the purpose of the first series of test to determine such coefficients for a variety of culvert shapes. Metal, concrete, and plastic model pipes will be tested under a number of hydraulic conditions. It is estimated that the work will be completed by September 1985. Just as with the structures laboratory testing program, the hydraulics staff work will be supplemented by an outside support contract.

Subsequent experiments in the hydraulics laboratory in future years will seek to provide experimental verification of pipe flow quantities, determine the best shape configuration and placement of spur dikes in rivers to effect the maximum protection of bridges, and conduct fundamental tests on the mechanics of stream behavior to observe the effects of obstructions in stream beds such as bridge piers and abutments. The new laboratory is best suited for studying water flow in long, narrow channels and conduits.

Reference: Staff study No. 25H4-023, Risk Analysis Philosophy for Drainage Design.

Staff study No. 25H3-012, Long Span and Special Shape Culvert Design Criteria

AERODYNAMICS LABORATORY

The George S. Vincent Memorial Wind Tunnel is a unique testing facility for aerodynamic investigations of cable suspended structures. This laboratory has for over 30 years provided an important service to the bridge design profession by the testing of scale models of suspension bridges and in the last few years also cable stayed bridges. This laboratory combines the service function of checking new designs of suspended bridges with fundamental investigations into the nature of the aerodynamic behavior of long span bridges in general.

The present experiments in progress deal with tests on the model of the Deer Isle to Sedgewick, Maine, suspension bridge. This work was requested by the State of Maine and represents a typical example of cooperation between a state, their consultants, and the specific experts at the Turner-Fairbank Highway Research Center. In this case the object of the tests is to aid the consultant in the design of rehabilitation schemes for this 45 year old bridge. It is expected that the need for such cooperative tests will continue in the future. Since plans for an expanded aerodynamics laboratory had to be abandoned for lack of funds, the existing laboratory is being modified at a modest scale to give us the capability for making model tests in a controlled turbulent wind. Present capabilities use only a smooth laminar flow.

Reference: Staff study No. 25A2-052, The Aerodynamic Response of the Deer Isle Suspension Bridge.

CONCRETE TECHNOLOGY LABORATORY

A fruitful research program on bridge corrosion problems continues in the concrete and corrosion laboratories, which include a unique outdoor bridge deck exposure site at the Research Center. Results from this test series have contributed greatly to an understanding of the corrosion problem of steel in concrete which has been translated into longer bridge life through the development of corrosion inhibiting systems such as epoxy-coated reinforcing bars, wax bead concrete, and cathodic protection systems.

The concrete and aggregate testing laboratories are used for making test samples for the exposure site, testing concrete mixture designs to satisfy special requests of our field offices, (Woodrow Wilson Bridge, E. Huntington Bridge), and for training field engineers(Region 3).

Future work will concentrate on the corrosion protection of prestressed steel reinforcement and the continued improvement of the cathodic protection technology. It is planned to apply the corrosion protection systems to other superstructure bridge elements as well as to substructure and foundation elements. It is also planned to investigate the use of very high strength concretes of 8,000-12,000 psi strength for structural applications. Supplemental outside contract help has been used in the bridge corrosion program and will be used again in the future.

Reference: Staff study No. 24B1-012, Time to Corrosion

CHEMISTRY LABORATORY COMPLEX

This complex consists of the following labs: Chemistry(F131), Spectroscopy and Chromatography(F121), Paint and Coatings, and Electron Microscopy(F117).

Work in this complex continues, as it has in the past, along two directions: staff research, and solution to technical problems submitted on a quick-response basis by State agencies and FHWA field and headquarters units.

In the area of staff research, recent work has focused on development of a specification for epoxy thermoplastic pavement marking material; quantification of the structure and deicing capability of the rock salt substitute - Calcium Magnesium Acetate (CMA); and the chemical characterization of asphalts, synthetic bitumens, and asphalt-additive mixtures by high pressure liquid chromatography and thermal analysis with an eye toward developing possible correlations to physical properties and field performance.

Recent field support problems examined in the laboratory complex have varied from the possible causes of blackening of pavement markings in Saudi Arabia, to determining if a traffic paint had been adulterated, and microscopic examination of specimens of bridge paint that is failing prematurely.

Future work is envisioned to continue to balance staff research of a more basic nature with day-to-day response to real field problems. It is planned to conduct research programs on the influence of metal surface properties on coatings failure; the film forming properties of coatings for bridge steel; and the relationships between the chemical makeup and the performance of asphalts and new, synthetic bitumens.

Reference: Staff study No. 24F2-022, Chemical Determination of Anti-Stripping Additives on Asphalt.

Staff study No. 24G1-533, Chemical and Physical Characterization of Binder Materials.

INSPECTION, FRACTURE, METALLURGY

There are several smaller laboratories which have the purpose of providing material characterization of bridge construction materials and thus these services supplement the work in the larger structures laboratory. We have been specially active in investigating the brittle fracture behavior of bridge steels for a number of years and this activity will continue. Closely allied with the fracture work has been the development of bridge inspection capabilities. Most of this work has concentrated on the better detection of fatigue cracks in welded joints and the better definition of flaws in large members such as eyebars.

The fracture and metallurgy laboratory is also quite often called on to inspect and determine the properties of a specific piece of steel sent to us by a State from an existing bridge under rehabilitation. Thus we provide an important service at times where an impartial opinion is needed. It is expected that such services will need to be continued in the future.

Reference: Staff study No. 25L2-012, Inspection and Evaluation of Bridge Steels and Structural Members.

FOUNDATION LABORATORY

The foundation testing capabilities at the Turner-Fairbanks Highway Research Center have been expanded recently to provide an outdoor pile testing facility for fullscale pile tests. For several years experiments on scale model single pile and pile groups have been in progress in the existing soil mechanics laboratory. The purpose of the tests is to determine pile group behavior in a variety of soils. The technical problem to be solved is the development of a reliable relationship between scale model piles and fullscale piles and pile groups. Fullscale pile tests are extremely expensive and they involve very large forces.

The present series of tests in the laboratory are made in carefully compacted sand beds and they involve both steel and wood piles, with the model scales varying from one third to one fiftieth of full scale. The sand model scale tests should be completed by April of 1984, after which fullscale tests in sand will be started in the outdoor facility. Comparisons with single pile and pile group behavior in the field will also be made.

This pile group behavior laboratory study is a very comprehensive study and will continue for a number of years. As with the other major staff studies, a specific outside support contract will supplement the laboratory study.

Reference: Staff study No. 24H2-032, An Investigation of Scale Effects Between Model and Fullscale Pile Groups.

ENVIRONMENTAL INSTRUMENTATION LABORATORY

The new Environmental Instrumentation Laboratory will facilitate highway traffic noise research. Portability of both noise instrumentation and a desktop computer system allows for on-site data analysis during traffic noise investigations. Currently, staff research is focused on two areas" (1) investingating the propagation of traffic noise around residential buildings in urban settings, and (2) developing and applying an automated technique for surveying the propagation of noise over a variety of terrains. Plans for the laboratory include interfacing the portable desktop computer to the DOT ANDOL computer. This will enable field data to be automatically input to programs run on the mainframe ANDOL computer. In this way, computerized noise models developed under administrative contract can be evaluated with considerable savings in staff time.

Reference: Study staff 23F4-722, "Urban Noise Study"

Study staff 23F4-732, "Acoustical Characterization of Ground Cover Near the Highway Right of Way"

BITUMINOUS MIXTURES LABORATORY

Much dissatisfaction has been expressed over current methods used for approval of chemical anti-strip additives and with test methods available for the identification of the stripping potential of an asphalt mix. The bituminous mixtures laboratory will be used in a staff effort to evaluate the effectiveness of various laboratory testing procedures including the Lottman type of test, dynamic loading tests, and other less-sophisticated tests. Four State highway departments have been contacted to provide asphalt-aggregate materials and mix proportions of known field-demonstrated stripping potential. Using these materials, a laboratory stripping investigation will be conducted in an attempt to find a test to accurately correlate with field performance.

In addition, the TFHRC asphalt plant will be used to produce the asphalt concrete for paving some experimental test sections on the grounds of the TFHRC complex. The actual mix design will be performed in the bituminous mixtures laboratory. After construction, field core specimens will be brought into the laboratory to examine characteristic changes with time.

Reference: FCP 24C4-014, "Evaluation of Asphalt-Aggregate Stripping Tests"

PAVEMENT PERFORMANCE LABORATORY

The initial experiments in the new Pavement Performance Laboratory will involve work within two different areas of pavement research technology. These areas are: (a) paving materials characterization and pavement design, and (b) evaluation of pavement condition measurement equipment.

The major work efforts will develop procedures to characterize paving materials based on laboratory mechanical tests, field response tests and field performance data. Mechanistic strength, stiffness, fatigue, permanent deformation and correlation properties will be determined for various types of materials. The types of laboratory tests to be studied include cylindrical compression, indirect tension and beam fatigue.

The effort in pavement evaluation will concentrate on the evaluation of field deflection and wave propagation devices for the rapid estimation of in-place material properties.

Other work will involve modifications to and calibrations of pavement condition measurement equipment. Specifically, the friction texture meter will be calibrated and infrared height sensors will be added to the survey vehicle. It is expected that this kind of work will continue in the future, especially to evaluate new pavement materials.

Reference: Staff Study No. 24A1-011. Paving Materials Characterization and
Pavement Design

General Support Facilities

Some of the general support services such as fabrication and maintenance of electronic instrumentation, is provided by the major research laboratories described elsewhere. There remains, however, certain general supporting functions which must be separately identified.

A Research, Development, and Technology Computer Center, linked to the DOT Transportation Computer Center, provides general support to all technical divisions for computer services and some software development support. This facility currently occupies space in the ground floor of the Fairbank Building. A major improvement in the computer equipment and additional space allocations for the support contractor are now in progress.

The shop complex has been reduced to a small machine shop to be operated by a support contractor who can also provide for major equipment fabrication and design services at his own facilities. Our requirements for woodworking, painting, and general minor construction will be furnished by the shops managed by the Office of Administration for general plant maintenance and security.

A report depository and distribution center will be established in the attic of the old Annex Building and managed by personnel of the National Highway Institute and a support contractor.

The remainder of the support spaces consist of the building services and conference rooms, storage, and display areas.

U.S. Department of Transportation
Office of the Secretary of Transportation

Office of Assistant Secretary

400 Seventh St., S.W.
Washington, D.C. 20590

August 16, 1983

Mr. Albert Gore, Jr.
Chairman, Subcommittee on
Investigations and Oversight
U.S. House of Representatives
Washington, D.C. 20515

Mr. Dan Glickman
Chairman, Subcommittee on Transportation,
Aviation and Materials
U.S. House of Representatives
Washington, D.C. 20515

Dear Messrs. Gore and Glickman:

Enclosed are answers for the hearing record to the questions posed in your letter to me of July 27, 1983 (copy attached).

Please let me know whether I can provide any additional information.

Sincerely,

Charles Swinburn
Deputy Assistant Secretary for
Policy and International Affairs

Enclosures

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JAMES H. SCHEUER, N.Y.
RICHARD L. OTTINGER, N.Y.
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General Counsel
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Minority Staff Director

July 27, 1983

Honorable Charles Swinburn
Deputy Assistant Secretary for Policy
and International Affairs
U.S. Department of Transportation
Washington, D. C. 20590

Dear Mr. Swinburn:

As we mentioned at the highway transportation infrastructure research hearing on June 16, 1983, we have some additional written questions, concerning the subject matter of the hearings, to put to the witnesses from the Department of Transportation. The questions are enclosed with this letter. We are sending them to you for further distribution and coordination of responses.

Since we wish to publish the report of the hearings as quickly as possible, we will appreciate timely replies.

Sincerely,

Albert Gore Jr.
ALBERT GORE, JR., Chairman
Subcommittee on Investigations
and Oversight

Dan Glickman
DAN GLICKMAN, Chairman
Subcommittee on Transportatic
Aviation and Materials

AG/DG:Ssw
Enclosure

ADDITIONAL QUESTIONS FOR THE HEARING RECORD

1. The technologies listed below include those mentioned by Administrator Ray Barnhart, in the foreword to the 1982 Annual Report of the Federally Coordinated Program of Highway Research and Development, as highlights of the Federal R&D program. When was research in each of the technology areas begun?

   How much is the total of FHWA, HPR, and NCHRP expenditures to date in each area?

   What is the current level of effort?

   Why, if the technologies are so promising, and expected cost savings so great, are they still in the research shop and not in routine use in the field?

   What plans exist for accelerating efforts in the most promising areas so that the estimate savings can begin to be realized in the near term?

   - o Alternate Deicers
   - o PACE (Performance of Alternative Coatings in the Environment)
   - o IRT (Infrared Termography)
   - o CP (Cathodic Protection)
   - o Sulphlex (chemically modified sulfur)
   - o Asphalt paving materials recycling
   - o Concrete strucuture rehabilitation in place
   - o Pavement overlays and composite pavements
   - o Pothole repair techniques

2. Mr. Lamm states in his testimony that "the long-range research activities in our "FHWA" programs have been somewhat reduced in the past several years." Please submit for the hearing record the following information arranged appropriately in tables.

   (1) Total DOT R&D obligations and outlays each year from 1972 to 1984 (est.) in current and constant 1972 dollars. Show the percentages these dollar amounts represent of total DOT outlays each year.

   (2) Total FHWA R&D obligations and outlays each year from 1972 to 1984 (est.) in current and constant 1972 dollars. Also show the major components of

the totals, such as the FHWA contract research and staff research, and the NCHRP and HPR program. Show the percentages these dollar amounts represent of total FHWA outlays each year.

(3) Estimated research outlays from the total HPR funds apportioned to the States each year from 1972 through 1984 (est.), in current and constant 1972 dollars, including the NCHRP contributions. Show the percentages the dollar amounts represent of the total HPR fund apportionments each year.

3. Mr. Lamm mentioned the new facilities recently dedicated at the Turner-Fairbank Research Center. Will all of the new laboratories be fully equipped and staffed by the end of 1983?

   What is the schedule?

4. Earlier in the hearings opinion was expressed that the new Turner-Fairbank research and testing facilities were good but if there was no long-term plan for their use, investment in the new building was a mistake. Is there a detailed multiyear work plan prepared for the increased capabilities of the Research Center?

   What major research activities and projects are scheduled in the next year?

   Please submit for the record your detailed long-term plans and schedules for the economic and effective use of the increased research and testing capabilities at the Turner-Fairbank Research Center. Include the Department's rationale for the substantial reduction in FHWA technical and research personnel shortly before this large new facility was completed.

5. Opinion was expressed in the hearings that the highway research community was an "old boy's club", with insufficient replacements of retiring older expert staff by younger, well-trained research scientists, technicians and engineers. Similar concern about the problem has been noted among senior research engineers in the profession. What long-term training support programs exist in FHWA which address the problems of attracting top quality young people to careers in highway research and technology in numbers sufficient to at least meet future staff replacement requirements, both in FHWA and throughout the country?

6. A research and testing project roughly equivalent in scope and scale to the AASHO Road Test program begun in 1958 was estimated to cost more than $90 million in 1983 dollars. If some project of that scale was undertaken, could it be essentially accomplished and coordinated at the Turner-Fairbank Research Center within a reasonable time horizon?

7. Several witnesses suggested that highway research and development could benefit from some operational and organizational changes. DOT staff recommended some reorganizations in 1981, and recently the President's Private Sector Survey on Cost Control (PPSSCC) recommended some reorganization of DOT research activities. Please submit for the hearing record a detailed response to recommendations F-1, F-2 and F-3, together with the relevant sub-recommendations, of the PPSSCC report on "Research and Development within the Department of Transportation". Delinate the actions planned, their time horizons, or the reasons why any one of the recommendations will not be accepted. Specify any disagreements with the PPSSCC report's estimates of cost savings which would result from adoption of the recommendations and the bases of the differing DOT estimates.

Highlights of the FHWA RD&T Program

Question 1: The technologies listed below include those mentioned by Administrator Ray Barnhart, in the foreword to the 1982 Annual Report of the Federally Coordinated Program of Highway Research and Development, as highlights of the Federal R&D program. When was research in each of the technology areas begun?

How much is the total of FHWA, HP&R, and NCHRP expenditures to date in each area?

What is the current level of effort?

Why, if the technologies are so promising, and expected cost savings so great, are they still in the research shop and not in routine use in the field?

What plans exist for accelerating efforts in the most promising areas so that the estimate savings can begin to be realized in the near term?

- Alternate Deicers
- PACE (Performance of Alternative Coatings in the Environment)
- IRT (Infrared Thermography)
- CP (Cathodic Protection)
- Sulphlex (Chemically Modified Sulfur)
- Asphalt Paving Materials Recycling
- Concrete Structural Rehabilitation in Place
- Pavement Overlays and Composite Pavements
- Pothole Repair Techniques

Answer: Each of the technologies identified are explained in the paragraphs that follow. In general, the application of a new technology to highways cannot be confined to a specific date. The process is normally evolutionary and the initial application of a new technology through an experimental or demonstration project is very valuable in refining and improving later applications of the technology. Our R&D programs are built around a process of research, evaluation, revision, development, field testing, and implementation. Many of the following technologies are in the latter stages of this process.

Alternate Deicers

Started:	Expenses through FY 1982:	Current Expenses
1981	$583,000	$787,000

Calcium Magnesium Acetate (CMA) is an alternative deicer found to be as effective as sodium chloride. Prior to widespread field application of CMA, additional tests will be conducted to determine melting characteristics and metal corrosion; effects on soils, plants, and water supplies; concrete compatibility and skid properties; and determined criteria for applying CMA. In addition, a production process has to be developed to provide the lowest production cost for CMA since it is a product that has only been produced in the laboratory.

FHWA is accelerating the use of CMA by starting testing and production studies concurrently. FHWA is also sponsoring field trials under a pooled fund HP&R project using small quantities of CMA in two States. An additional four States are conducting field studies using their own research funds and their own materials.

PACE (Performance of Alternative Coatings in the Environment)

Started:	Expenses through FY 1982:	Current Expenses
1975	$380,000	$150,000

PACE is a two phase, long-range pooled-fund study to evaluate the performance of alternative metal coatings under typical environmental conditions. The study is being based on the long-term performance of steel panels, each coated with a different coating system and then allowed to weather in three different environments which represent coastal, heavy industrial and light industrial. This effort is still in the research phase because the weathering process is a long-range phenomenon and can only be evaluated after years of exposure. The 6-year data, which is due in 1984, will identify those coatings which contain neither lead nor chromium and which promise to perform as well as the widely used red lead paints of today. At that point, recommendations will be made on paint compositions and model specifications will be written for use by the States in selecting alternative coatings. The state of the art of evaluation of coatings does not allow drawing firm conclusions based on anything other than long-term field exposure tests.

The adoption of alternative coatings will be accomplished by recommending paint compositions and model specifications to highway administrators, bridge engineers, and bridge maintenance engineers in the form of practical guidelines for application of the coatings. Full-scale application on in-service bridges will be sponsored in order to evaluate the coatings under "real-world" application conditions and to build confidence on the part of the user that the coatings are cost-effective.

IRT (Infrared Thermography)

Started:	Expenses through FY 1982:	Current Expenses
1982	$ 25,000	$ 0

It has been only recently determined that infrared thermography is a very promising technique for evaluating condition and future performance of coatings. Considerably more research effort is necessary before this technique will provide results which can be used with confidence. As with any accelerated predictive technique, it is a must to correlate test results with the results of standard, long term tests before such confidence can be developed. Once this technique is fully researched and developed, it can be used to replace the long term exposure evaluations of coatings such as those being conducted under PACE. There are no accelerated plans to develop this technology.

Cathodic Protection (CP)

Started:	Expenses through FY 1982:	Current Expenses
1974	$1,100,000	$715,000

The application of cathodic protection to highway bridges is a continually evolving technology and considerable research is still being done on effective CP systems for highway bridge decks and substructures. However, significant strides have been made in transferring this complex corrosion engineering solution to the practicing bridge maintenance engineer. Demonstration of CP by actual installation has occurred in 12 States and technical presentations have been made in 21 other States. At the same time, a newly developed type of bridge deck CP is being installed and evaluated in two States. This nonoverlay system with anode wires in closely spaced slots is being actively promoted to the States. FHWA Office of Implementation is currently developing a manual on CP systems which when completed in 1983 will provide the States with up-to-date, practical guidelines on implementation of CP technology to bridge decks. Throughout this effort, research and development of different systems will continue and new systems will be implemented as soon as they are ready.

The Office of Implementation will continue its technology transfer effort in FY 1985 by developing a comprehensive but practical training course in corrosion engineering and cathodic protection for bridge deck and substructure applications. The course will be given to bridge maintenance engineers in all interested States and should provide significant impetus to implementation of CP technology. The timing of this course is a balance between the need to achieve an adequate level of development of field tested systems and the urgent need for implementation to minimize bridge deck deterioration.

Sulphlex (Chemically Modified Sulfur)

Started:	Expenses through FY 1982:	Current Expenses
1976	$2,200,000	$134,000

Sulphlex is a plasticized sulfur binder that can completely replace the asphalt cement in an asphaltic concrete paving mix. Initial research results of laboratory tests on this material were very promising. As a result, full-scale field projects were constructed by seven highway agencies and are now being evaluated. These evaluations will continue for several more years in order to determine the long-term performance characteristics of the material. At the present time, there is little interest currently by highway agencies in using Sulphlex on additional projects due to the current high price of sulfur and adequate supplies of asphalt. In addition, sufficient quantities of sulfur are not readily available in many parts of the country. If these conditions reverse themselves and the long-term performance of the current projects prove satisfactory, the use of Sulphlex is expected to increase significantly in the future.

Asphalt Paving Materials Recycling

Started:	Expenses through FY 1982:	Current Expenses
1976	$5,500,000	$325,000

The general concept of how to do asphalt pavement recycling is no longer considered a research item. FHWA and many State highway agencies fully support this concept. Most States have constructed at least one recycling project. Several States allow the regular use of various recycling construction procedures and allow contractors to bid on projects where recycling is an alternative to other rehabilitation techniques. During the next 3 years, the Office of Implementation will be providing support to collect design, construction, maintenance, and pavement performance information on recycling projects constructed after 1980. This information will be used to establish a comprehensive data base from which pavement performance over a period of time and life cycle costs can be established. More realistic figures on these items are essential to highway agencies in setting priorities for their pavement programs and maintaining the highway system.

Concrete Structure Rehabilitation in Place

Started:	Expenses through FY 1982:	Current Expenses
1960's	$1,000,000	$135,000

The capability of rehabilitating concrete structures in place by replacing badly deteriorated bridge decks with precast concrete panels already exists. Field applications are becoming more and more common and successful examples will breed more interest and more widespread use. The Woodrow Wilson Bridge is an excellent example of a very difficult deck rehabilitation in which precast panels have played a vital role. Traffic is being maintained throughout the construction and the project will very likely be finished well ahead of schedule. FHWA will continue to encourage use of precast deck panels. FHWA also plans to prepare a manual which will illustrate the successful use of precast panels and also cover the very important feature of connections between panels. This manual will be used to educate and encourage bridge engineers to use this approach to deck rehabilitation. The Demonstration Projects Division will also conduct efforts to evaluate short and long term evaluation of precast deck panels and this information will be useful in future designs.

Acceptance of this technology is good; therefore, there are no current plans to accelerate research and development in this technology.

Pavement Overlays and Composite Pavements

Started:	Expenses through FY 1982:	Current Expenses
1973	$5,500,000	$382,000

Pavement Overlays

The decision when or if to overlay and the design of the overlay itself is a very complicated process due to the variabilities of road condition, traffic, material, and rehabilitation strategy alternates, to name a few. Recent research has been aimed at models that can predict performance of the various alternatives given deflection measurements on the existing roadway, projected traffic volumes and properties of the in-place and proposed overlay materials. Some very promising techniques have been developed by research and tried on a very limited basis.

In fiscal year 1984 it is planned to have four State agencies test and evaluate the various overlay design procedures developed by research. The results of these field verification studies will determine if they appear to have widespread application and warrant promotion for routine use in the field. Consideration will be given to modify existing computer programs so these procedures can be run on microcomputers, if appropriate. This step will reduce the time needed to get the more promising overlay design procedures into routine use.

Pavement Overlays and Composite Pavements (continued)

Composite Pavements

Research has developed an Interim Guide for Design of Premium Pavements which includes a recommended procedure for the design of composite pavements. This Interim Guide is currently being published.

Planned work in fiscal year 1984 includes evaluating the effectiveness of these proposed designs in four to five States to establish life cycle costs for the alternate designs (including composite pavements). Results from this study will be used as the basis for FHWA technical advisories to establish guidelines/criteria for the composite design method as well as others. Recommendations for revising the AASHTO Guide for the Design of Pavements Structures will also be made where appropriate. These efforts should reduce the time needed to get the tested and proven design procedure into routine use.

Pothole Repair Techniques

Started:	Expenses through FY 1982:	Current Expenses
1978	$790,000	$300,000

With the exception of the search for better techniques for use under special environmental conditions, the work on pothole repair is in the implementation phase. Distribution of the latest report "Pavement Patching Guidelines" began in May. To date over 1,500 copies have been requested by State, county, and city governments, and universities.

We are promoting the use of the techniques in our "Pavement Patching Guidelines" through our Technology Transfer specialists in the field, the Rural Transportation Assistance Program and bulletins in appropriate journals. Because of the current demand for information in this area, we will have to reprint this report to fulfill future requests.

Department of Transportation and FHWA R&D Funding

Question 2: Mr. Lamm states in his testimony that "the long-range research activities in our 'FHWA' programs have been somewhat reduced in the past several years." Please submit for the hearing record, the following information arranged appropriately in tables.

(1) Total DOT R&D obligations and outlays each year from 1972 to 1984 (est.) in current and constant 1972 dollars. Show the percentages these dollar amounts represent of total DOT outlays each year.

Answer (1): For total DOT R&D obligations and outlays each year from 1972-1984 see attached table.

(2) Total FHWA R&D obligations and outlays each year from 1972 to 1984 (est.) in current and constant 1972 dollars. Also show the major components of the totals, such as the FHWA contract research and staff research, and the NCHRP and HP&R program. Show the percentages these dollar amounts represent of total DOT outlays each year.

Answer (2): For total FHWA R&D obligations and outlays each year from 1978-1984 see attached table.

Department of Transportation
Research and Development
($ in millions)

Fiscal Year	Obligations a/	Outlays a/	% of Total DOT Outlays
1972 Actual	$351	$274	3.6%
1973 Actual	311	312	3.8%
1974 Actual	370	328	4.0%
1975 Actual	291	307	3.3%
1976 Actual	274	303	2.5%
1977 Actual	321	311	2.5%
1978 Actual	372	326	2.4%
1979 Actual	357	340	2.2%
1980 Actual	374	377	2.0%
1981 Actual	420	418	1.9%
1982 Actual	309	349	1.8%
1983 Estimate	393	376	1.8%
1984 Estimate	519	451	1.8%

a/ Data extracted from the Special Analyses, Budget of the U.S. Government, and excludes research and development facilities.

19 August 1983

Department of Transportation
Research and Development
1972 Constant Dollars
($s in millions)

Fiscal Year	Obligations	Outlays	% of Total
1972	$351	$274	3.6%
1973	294	295	3.8
1974	322	285	4.0
1975	232	245	3.3
1976	207	229	2.5
1977	230	222	2.5
1978	248	217	2.4
1979	219	209	2.2
1980	211	212	2.0
1981	215	214	1.9
1982	149	168	1.8
1983	181	173	1.8
1984	227	197	1.8

Sources for Price Deflators:

FY 73-79, Economic Report of the President, January 1981.

FY 80-82, Survey of Current Business

FY 83-84, Estimates based on Special Analyses, Budget of the United States Government, Fiscal Year 1984.

FHWA R&D Obligations and
Outlays in Current and
Constant (1978 Base)
($ millions)

	Obligations		Outlays	
Year	Current	Constant	Current	Constant
1978	42.2	42.2	43.0	43.0
1979	45.3	37.9	41.1	34.4
1980	43.0	31.5	45.0	34.3
1981	38.3	29.2	42.2	32.2
1982	40.3	32.8	42.5	34.6
1983 (est.)	53.9	43.4	45.5	36.7
1984 (est.)	48.7	41.5	50.4	43.0

Excludes spending on the new Research Facility

Department of Transportation and FHWA R&D Funding

Question 2: Mr. Lamm states in his testimony that "the long-range research activities in our "FHWA" programs have been somewhat reduced in the past several years." Please submit for the hearing record, the following information arranged appropriately in tables.

(3) Estimated research outlays from the total HP&R funds apportioned to the States each year from 1972 to 1984 (est.), in current and constant 1972 dollars, including the NCHRP contributions. Show the percentages the dollar amounts represent of total HP&R fund apportionments each year.

Answer (3): Estimated research outlays from the total HP&R funds apportioned to the States each year from 1972 to 1984 in current and constant 1972 dollars including NCHRP contributions are shown on the attached table.

Current Dollars (x 1,000)

	1	2	3	4		5
	HP&R Research	NCHRP	TOTAL	Totals at 1972 Dollars* (3 x indices)	Indices	Percent Research of Total HP&R
1972	27,271	3,618	30,889	30,889	(1.0)	38.4% (80,408)
1973	27,940	3,618	31,558	28,780	(0.912)	39.2% (80,408)
1974	27,150	3,186	30,336	26,514	(0.874)	42.8% (70,828)
1975	26,889	3,581	30,470	24,284	(0.797)	38.2% (79,636)
1976	22,900	3,714	26,614	19,428	(0.730)	32.2% (82,579)
1977	18,500	3,741	22,241	15,013	(0.675)	16.5% (134,472)
1978	19,000	3,916	22,916	14,437	(0.630)	26.1% (87,793)
1979	21,000	4,106	25,106	14,762	(0.588)	27.5% (91,245)
1980	21,000	4,414	25,414	13,647	(0.537)	25.9% (98,095)
1981	22,200	4,579	26,779	13,416	(0.501)	26.3% (101,752)
1982	23,600	4,354	27,954	12,719	(0.455)	28.8% (96,756)
1983	31,200	6,813	38,013	17,068	(0.450) est.	25.1% (151,398)
1984	40,000 est.	7,500 est.	47,500	-		28.7% (165,000) est.

* Using Construction Rate Indices.

Turner-Fairbank Highway Research Center (TFHRC)

Question 3: Mr. Lamm mentioned the new facilities recently dedicated at the Turner-Fairbank Highway Research Center. Will all of the new laboratories be fully equipped and staffed by the end of 1983? What is the schedule?

Answer: As noted in the report "Plan for the Utilization of Laboratories 1983-1986" at TFHRC transmitted to your committee under separate cover, we are still in the process of installation of major basic equipment in the new laboratories. The process has been funded by a combination of our normal budget for scientific equipment over the past several years and a number of special contracts such as one for the development of HYSIM, the highway driving simulator. This basic equipment will all be in place about the end of 1983. Additional equipment for modernization of some of the older laboratories, and to meet the special requirements of specific experiments beyond that time are expected to be acquired under our normal budget for such equipment, with a few exceptions. One of these is equipment for accelerated loading tests of full scale pavements, which is still in the design stage, and is tentatively budgeted for construction in FY 1984-1985.

Our staffing problem is indeed difficult. At this point in time we do not plan to seek specific authorization for additional personnel, but rather to supplement the resources of our staff with support contractors for functions which are suitable, such as data processing, electronic and mechanical fabrication, routine maintenance of research tests, and short term periodic requirements for substantial numbers of technicians to set up major experiments.

Plan for Utilization of Laboratories 1983-1986

Question 4: Earlier in the hearings opinion was expressed that the new Turner-Fairbank research and testing facilities were good but if there was no long-term plan for their use, investment in the new building was a mistake. Is there a detailed multi-year work plan prepared for the increased capabilities of the Research Center?

What major research activities and projects are scheduled in the next year.

Please submit for the record your detailed long-term plans and schedules for the economic and effective use of the increased research and testing capabilities at the Turner-Fairbank Highway Research Center. Include the Department's rationale for the substantial reduction in FHWA technical and research personnel shortly before this large new facility was completed.

Answer: A report "Plan for the Utilization of Laboratories 1983-1986" has been forwarded under separate cover and should provide adequate answers of immediate utilization of the new facilities over the next 3 years. Beyond that, we expect an expansion of most of the same areas of activity, especially in the experimental work on pavements, and the human factors work related to safety and traffic flow.

The reduction of personnel in the research function during FY 1982-1983 was an undesirable but necessary function due to the overall reductions in FHWA staffing required. In the judgment of the Administrator, anticipating the expansion of the Federal-aid program which became fact in the legislation of December 1982, it was not feasible to absorb these reductions by further cuts in the field structure which we depend upon for our delivery system for this program.

Background of FHWA RD&T Staff

Question 5: Opinion was expressed in the hearings that the highway research community was an "old boy's club," with insufficient replacements of retiring older expert staff by younger, well-trained research scientists, technicians and engineers. Similar concern about the problem has been noted among senior research engineers in the profession. What long-term training support programs exist in FHWA which address the problems of attracting top quality young people to careers in highway research and technology in numbers sufficient to at least meet future staff replacement requirements, both in FHWA and throughout the country?

Answer: Recruitment and training of new personnel to provide a continuous supply of young talent has long been of concern to the FHWA. Recently the agency has been able to reinstate its training program and will have candidates this year. Some of these trainees in the past have found their permanent career in research and development, but there is a need in this function for a number of specialists other than civil engineers or the other backgrounds typical of our regular trainees. For this purpose, FHWA has recruited from the general R&D community and has also invested in the continuing education and training of existing staff. As a result, the present composition of the professional staff is shown on the attached page:

Professional Background	Number	Average Age	Degree Level BS	MS	Dr.
Civil Engineering					
Civil Engineers	53	43.1	25	25	3
Transportation and Traffic	21	43.6	8	11	2
Structures	12	46.6	2	10	-
Hydraulics	6	43.3	3	-	3
Materials and Pavements	21	45.4	7	12	2
Other Engineering					
Electrical and Electronic	7	46.9	5	2	-
Mechanical	6	54.0	2	2	2
Environmental	1	32.0	1	-	-
Nuclear Engineer	1	42.0	-	-	1
Metallurgist	1	63.0	1	-	-
Other Scientific Disciplines					
Chemist	8	51.6	3	-	5
Physicist	5	38.2	2	1	2
Psychologists	5	47.6	1	2	2
Mathematician/Statistician	3	40.6	-	3	-
Statistician	2	50.0	-	2	-
Ecologist	1	33.0	-	1	-
Economist	1	33.0	1	-	-
Geologist	3	42.7	-	1	2

1958 AASHO Road Test Program

Question 6: Could an AASHO Road Test type research program be accomplished and coordinated at the Turner-Fairbank Highway Research Center within a reasonable time?

Answer: Planning for the AASHO Road Test at Ottawa, Illinois, was formally started in 1951. Construction began in 1956 and test traffic was started in 1958, and ended with some special studies in 1961. The work involved over 400 Army test drivers and their officers, from 50 to 100 engineers, and technicians as permanent staff, and hundreds of other persons serving as observers and advisors. Total cost of the test was near $30,000,000. The test was mainly a pavement experiment although it also contained 18 test bridges.

It is unlikely a test of that magnitude could be accomplished presently for less than $200,000,000 and it could not be conducted at the Turner-Fairbank Highway Research Center because of lack of space to build a number of miles of roads, nor could it be managed or coordinated with our present staff. The technical question of the value of a similar pavement and bridge test road has not been addressed and may be unnecessary. A National Initiative of Pavement Rehabilitation and Design is presently underway in FHWA. One element of this initiative is addressing the need for a future full-scale road test and evaluating an accelerated testing system to allow more rapid evaluation of new pavements, rehabilitation techniques and materials.

QUESTION 7: PPSSCC RECOMMENDATIONS

QUESTION: Several witnesses suggested that highway research and development could benefit from some operational and organizational changes. DOT staff recommended some reorganizations in 1981, and recently the President's Private Sector Survey on Cost Control (PPSSCC) recommended some reorganization of DOT research activities. Please submit for the hearing record a detailed response to recommendations F-1, F-2 and F-3, together with the relevant sub-recommendations, of the PPSSCC report on "Research and Development within the Department of Transportation." Delineate the actions planned, their time horizons, or the reasons why any one of the recommendations will not be accepted. Specify any disagreements with the PPSSCC report's estimates of cost savings which would result from adoption of the recommendations and the bases of the differing DOT estimates.

ANSWER: With over $300 million expended each year on its R&D programs, the Department agrees with the President's Private Sector Survey Recommendation (F-1), that there needs to be a policy framework for structuring its R&D. This policy should originate at the Secretarial level, and serve as the guidance for the operating administrations when they propose R&D projects. Moreover, there does not currently exist any mechanism for the private sector to recommend to the Department any changes in the Federal transportation R&D thrust. An organizational R&D entity in the Office of the Secretary is a practical solution to this problem.

The PPSSCC task force projected a large savings based on the premise that DOT's R&D products can be commercialized. However, much of DOT's R&D is oriented toward safety regulation or policy formulation which by its very nature does not tend to produce a discrete commercial product, e.g., an improved automobile bumper, or more effective air traffic control system. In certain areas, such as the maritime and highway industry, the Department has witnessed only limited private sector interest, and a clear lack of private sector venture capital. While the Department believes the task force recommendation has merit, we are less optimistic about the size of the potential savings. We will approach this issue, however, to maximize whatever savings are possible.

With respect to Private Sector Survey Recommendation F-2, regarding a new R&D structure and management review process, the Department is considering several options. One option is to staff an existing office, i.e., the Office of Transportation Research and Technology. The other option is to create a science advisor position that reports to the Secretary. The decision of which approach will be taken will be based on a final assessment within the next six months of how strong an R&D presence is needed in OST. Similarly, the Department supports the Private Sector Survey conclusion that a management review process is needed, but, until a senior OST R&D official is in place, we cannot state how that process will work.

Finally, the task force's Recommendation F-3 was rather specific in its proposed process for prioritizing R&D. We believe the advisory group concept is sound; however, the Department cannot rely on investors alone to determine what DOT's R&D program should consist of. Nor do we believe that OMB should make decisions regarding DOT's R&D program on a project-by-project basis. We concur with the concept behind the task force recommendation that DOT perhaps should have a broader based external input in the development of its annual and long-range R&D program; the Department will consider the procedure suggested by the PPSSCC in the development of the OST role in R&D for the Department.

NATIONAL RESEARCH COUNCIL
TRANSPORTATION RESEARCH BOARD
2101 Constitution Avenue Washington, D.C. 20418

63rd ANNUAL MEETING
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August 30, 1983

Honorable Albert Gore, Jr.
Chairman
Subcommittee on Investigations
and Oversight
U.S. House of Representatives
1131 Longworth Building
Washington, D.C. 20515

Dear Congressman Gore:

During my recent appearance before the U.S. House of Representative's Subcommittee on Investigations and Oversight and the Subcommittee on Transportation, Aviation, and Materials of the Committee on Science and Technology, you asked that I provide information for the Record. Specifically, I was to answer the following question: "Would annual reporting to Congress on the R&D accomplishments on truly national transportation research problems, perhaps through the National Research Council and the National Academy of Sciences, help give more focus to the current research programs?"

I believe that any such reporting should not be undertaken more often than every two to three years since a more frequent reporting would be too repetitive; research doesn't move that fast. In addition, I believe that it should emphasize those transportation elements primarily in the public sector, in other words -- highways, public transit, airports, ports, and waterways. Less emphasis should be given to railroads, aircraft or vehicle research programs since these, being in the private sector, will presumably be responsive to market forces. With these specifications, such a report could be useful in that it would require the accumulation and analysis of data on research efforts in what otherwise might be viewed as a very decentralized activity. Periodically examining the situation and putting it into perspective could be of help to decisionmakers and others with oversight responsibilities and could be a means of focusing attention on important issues that sometimes are given a low priority.

If I could provide you with additional information on this, I would be pleased to do so at any time.

Sincerely yours,

Thomas B. Deen
Executive Director

cc: Shirley Watson

The National Research Council is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering to serve government and other organizations